PRINCIPLES

OF

GEOLOGY:

BEING

AN INQUIRY HOW FAR THE FORMER CHANGES OF THE EARTH'S SURFACE

ARE REFERABLE TO CAUSES NOW IN OPERATION.

BY

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"The stony rocks are not primeval, but the daughters of Time."
LINNÆUS, *Syst. Nat.*, Ed. 5. Stockholm, 1748, p. 219.

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PRINCIPLES OF GEOLOGY.

BOOK IV.

CHAPTER IX.

NEWER PLIOCENE FORMATIONS OF SICILY.

Growth of submarine formations gradual — Their rise above the level of the sea — Their present position proves modifications of the earth's crust at great depths, during the Newer Pliocene period — Alterations of the surface of Sicily during and since its emergence — Forms of the Sicilian valleys — Sea cliffs — Proofs of successive elevation (p. 8.) — Valleys in the Newer Pliocene districts correspond in form to those of other regions — Migrations of animals and plants since the emergence of the newer Pliocene strata — Some species older than the stations they inhabit — Recapitulation.

HAVING in the last two chapters described the tertiary formations of the Val di Noto and Valdemone, both igneous and aqueous, I shall now proceed more fully to consider their origin, and the manner in which they may be supposed to have assumed their present position. The consideration of this subject may be naturally divided into three parts: first, we may inquire in what manner the submarine formations were accumulated beneath the waters; secondly, whether they emerged slowly or suddenly, and to what modifications in the earth's crust, at considerable depths below the

surface, their rise may be attributed; thirdly, the mutations which the surface and its inhabitants have undergone during and since the period of emergence.

Growth of submarine formations.—First, then, we are to inquire in what manner the subaqueous masses, whether volcanic or sedimentary, may have been formed. On this subject a few observations will suffice; for by reference to the two last books, the reader will learn how a single stratum, whether of sand, clay, or limestone, may be thrown down at the bottom [illegible] the sea, and how shells and other organic remains [illegible] become imbedded in it. He will also understand [illegible] one sheet of lava, or one bed of scoriæ and volcanic sand, may be spread out over a wide area, and how, at a subsequent period, a second bed of sand, clay, or limestone, or a second lava stream, may be superimposed, so that in the lapse of ages a mountain mass shall be produced.

It is enough that we should behold a single course of bricks or stones laid by the mason upon another, in order to comprehend how a massive edifice, such as the Coliseum at Rome, was erected; and we can have no difficulty in conceiving that a sea, three hundred or four hundred fathoms deep, might be filled up by sediment and lava, provided we admit an indefinite lapse of ages for the accumulation of the materials.

The sedimentary and volcanic masses of the newer Pliocene era, which, in the Val di Noto, attain the thickness of two thousand feet, are subdivided into a vast number of strata and lava streams, each of which were originally formed on the subaqueous surface, just as the tuffs and lavas, whereof sections are laid open in the Val del Bove, were each in their turn external additions to the Etnean cone.

It is also clear, that before any part of the mass of

submarine origin began to rise above the waters, the uppermost stratum of the whole must have been deposited; so that if the date of the origin of these masses be comparatively recent, still more so is the period of their rise above the level of the sea.

Subaqueous formations, how raised.—In what manner, then, and by what agency, did this rise of the subaqueous formations take place? We have seen that a vast area in Scandinavia has been slowly rising for centuries above its former level. We have also seen that in the year 1819, a tract of country in Cutch, more than fifty miles long and sixteen broad, was permanently upraised to the height of ten feet above its former position, and the earthquake which accompanied this wonderful variation of level is reported to have terminated by a volcanic eruption at Bhooj. It also appeared that when the Monte Nuovo was thrown up, in the year 1538, a large fissure approached the small town of Tripergola, emitting a vivid light, and throwing out ignited sand and scoriæ.* At length this opening reached a shallow part of the sea close to the shore, and then widened into a large chasm, out of which were discharged blocks of lava, pumice, and ashes. But no current of melted matter flowed from the orifice, although it is perfectly evident that lava existed below in a fluid state, since so many portions of it were cast up in the form of scoriæ into the air. It will be remembered that the coast near Puzzuoli rose, at that time, to the height of more than twenty feet above its former level, and that it has remained permanently upheaved to this day.†

On a review of the whole phenomena, it appears not improbable that the elevated country was forced up-

* Vol. II. p. 124. † Vol. II. p. 323.

wards by lava which did not escape, but which, after causing violent earthquakes, during several preceding months, produced at length a fissure from whence it discharged gaseous fluids, together with sand and scoriæ. The intruded mass then cooled down at a certain distance below the uplifted surface, and constituted a solid and permanent foundation.

If an habitual vent had previously existed near Puzzuoli, such as we may suppose to remain always open in the principal ducts of Vesuvius or Etna, the lava might, perhaps, have flowed over upon the surface, instead of heaving upwards the superficial strata. In that case there might have been the same conversion of sea into land, the only difference being, that the lava would have been uppermost, instead of the tufaceous strata containing shells, now seen in the plain of La Starza, and on the site of the Temple of Serapis.

But when we remember that the tertiary strata of the Val di Noto have attained the height of from fifty to two thousand feet, and in the central parts of Sicily, as at Castrogiovanni, an elevation of about three thousand feet above the level of the sea, are we prepared to suppose a solid support of igneous rock, equal in volume to the upraised tract, to have been generated below since the Newer Pliocene strata were formed? In reply to this question I may remark, that the entire mass of Iceland is said to be volcanic, an island 260 miles long by 200 in breadth, and which rises, in some spots, to the height of 6000 feet. Had the melted matter in this case been prevented from reaching the surface by the weight and tenacity of superincumbent rocks, it might, perhaps, have heaved up a district three times as extensive as Sicily. But whether we adopt this or any other hypothesis as the cause of elevation—whether we introduce the evolution

of gases, the liquefaction of rocks, or in cases like that of Sweden, their slow and gradual expansion by heat, on whatever mode of operation we speculate, it is still impossible to escape from the conclusion, that some very extraordinary change has taken place in part of the earth's crust, immediately underneath Sicily, since the Mediterranean was inhabited by the existing species of testacea. We must surely admit that the permanent upheaving of a country two or three thousand square miles in area, to an additional height of several hundred yards, implies either the intrusion of new mineral matter into the fundamental rocks, or some great modification in their character.

It would be superfluous to repeat here what has been said of the probable causes of volcanic agency, operating at considerable depths, or what has been called by some geologists *plutonic action.** But it is important to reflect, that the position of the Newer Pliocene strata, in Sicily and elsewhere, indicates that this action has been developed on a great scale since the recent species of testacea abounded. The formation of a cone, such as Etna, or of the sedimentary and volcanic rocks of the Val di Noto, are superficial mutations which are perfectly insignificant in a geological point of view, when compared with the contemporaneous changes above alluded to which must have been going on *out of sight.* The result of these operations may one day be exposed to view; but a great lapse of time will probably be required before masses formed or altered at great depths can be brought up to the surface.

> Quicquid sub terrâ est, in apricum proferet ætas
> Defodiet condetque nitentia.

* See book ii. chaps. xviii. and xix.

The deposits of our own period may sink down, and be hidden in the depths of the earth, when the plutonic formations of the Newer Pliocene era shall have become visible; and it may then be impossible to ascertain, by geological evidence, the relative date of rocks formed in the subterranean regions during the Newer Pliocene ages, and to prove that they were produced at precisely the same time with the limestone and argillaceous strata of the Val di Noto.

Changes of the Surface during and since the Emergence of the Newer Pliocene Strata.

Valleys. — Geologists who are accustomed to attribute a great proportion of the inequalities of the earth's surface to the excavating power of running water during a long series of ages, will probably look for the signs of remarkable freshness in the aspect of countries so recently elevated as the parts of Sicily already described. There is, however, nothing in the external configuration of that country which would strike the eye of the most practised observer, as peculiar and distinct in character from any other districts in Europe which are of much higher antiquity. The general outline of the hills and valleys would accord perfectly well with what may often be observed in regard to other regions of equal altitude above the level of the sea.

It is true that, towards the central parts of the island, where the argillaceous deposits are of great thickness, as around Castrogiovanni, Caltanisetta, and Piazza, the torrents are observed annually to deepen the ravines in which they flow; and the traveller occasionally finds that the narrow mule path, instead of winding round the head of a ravine, terminates abruptly

in a deep trench which has been hollowed out, during the preceding winter, through soft clay. But throughout a great part of Italy, where the marls and sands of the Subapennine hills are elevated to considerable heights, the same rapid degradation is often perceived.

In the limestone districts of the Val di Noto, the strata are for the most part nearly horizontal, and on each side of the valley form a succession of ledges or small terraces, instead of descending in a gradual slope towards the river-plain in the manner of the argillaceous formations. When there is a bend in the valley, the exact appearance of an amphitheatre with a range of marble seats is produced. A good example of this configuration occurs near the town of Melilli, in the Val di Noto, as seen in the annexed view (Fig. 86.) In the south of the island, as near Spaccaforno,

Fig. 86.

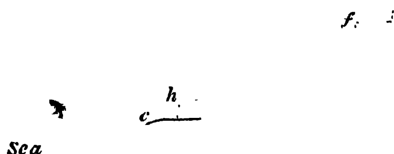


Valley called Gozzo degli Martiri, below Melilli.

Scicli, and Modica, precipitous rocks of white limestone, ascending to the height of five hundred feet,

have been carved out into the same form. It is not easy to account for this phenomenon; but it may perhaps be due to the action of the sea during the rise of the land, for every portion of the cliffs bordering these valleys may in its turn have been washed by the waves. We find evident signs of two periods of elevation in a long range of inland cliff on the east side of the Val di Noto, both to the north of Syracuse, beyond Melilli, and to the south beyond the town of Noto. The great limestone formation terminates suddenly towards the sea in a lofty precipice, *a*, *b*, which varies in height from 500 to 700 feet, and may remind the

Fig. 87.



English geologist of some of the most perpendicular escarpments of our chalk and oolite. Between the base of the precipice *a*, *b*, and the sea is an inferior platform *c*, *b*, consisting of similar white limestone. All the strata dip towards the sea, but are usually inclined at a very slight angle; they are seen to extend uninterruptedly from the base of the escarpment into the platform, showing distinctly that the lofty cliff was not produced by a fault or vertical shift of the beds, but by the removal of a considerable mass of rock. Hence we may conclude that the sea, which is now

undermining the cliffs of the Sicilian coast, reached at some former period the base of the precipice *a*, *b*, at which time the surface of the terrace *c*, *b*, must have been covered by the Mediterranean. Here, then, we have proofs of at least two elevations, but there may have been many others.

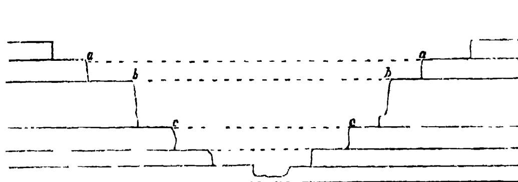
Suppose, for example, that a series of escarpments, *e*, *f*, *g*, *h*, once existed, and that during a long interval, free from subterranean movements, the sea advances along the line *c*, *b*, all preceding cliffs must have been swept away one after the other, and reduced to the single precipice *a*, *b*.

I have stated, in the second volume, that the waves washed the base of the inland cliff of Puzzuoli, in the Bay of Baiæ, within the historical era, and that the retiring of the sea was caused, in the sixteenth century, by an upheaving of the land to the height of twenty feet above its original level.* At that period, a terrace twenty feet high in some parts was laid dry between the sea and the cliff; but the Mediterranean is hastening by its encroachments to resume its former position, and the terrace will be eventually destroyed, and every trace of the *successive* rise of the land obliterated.

In those valleys where the opposite sides form a great flight of steps from top to bottom we may suppose the sea to have stood successively at many different levels, as at *a a*, *b b*, *c c*, in the annexed figure (88.); and if the separate movements of elevation followed each other more rapidly as the land continued to rise, then would the gradual contraction of the valley in its lower parts be explained, for the intervals of time

* P. 324.

Fig. 88.



would be shortened in which each successive excavation was accomplished. This hypothesis by no means requires that terraces and small precipices should be always formed on the opposite sides of each valley at corresponding levels; for the amount and depth of erosion by the waves would be determined by the set of the winds and currents, the varying hardness of the strata, the form of the ancient coast, and a variety of other accidents.

The line of some of the valleys near Lentini has evidently been determined mainly by the direction of the elevatory force, as there is an anticlinal dip in the strata on either side of the valley. The same is, probably, the case in regard to the great valley of the Anapo, which terminates at Syracuse.

I have been led into these observations, in order to show that the principal features in the physical geography of Sicily are by no means inconsistent with the hypothesis of the successive elevation of the country by the intermittent action of ordinary earthquakes. On the other hand, the magnitude of the valleys, and their correspondence in form with those of other parts of the globe, seem to lend countenance to the theory of the slow and gradual rise of subaqueous strata.

The excavation of valleys, as was before remarked, must always proceed with the greatest rapidity when the levels of a country are undergoing alteration from time to time by earthquakes; and it is principally when a country is rising or sinking by successive movements, that the power of aqueous causes, such as tides, currents, rivers, and land-floods, is exerted with the fullest energy.*

In order, therefore, to explain the present appearance of the surface, we must first go back to the time when the Sicilian formations were mere shoals at the bottom of the sea, in which the currents may have scooped out channels here and there. We must next suppose these shoals to have become small islands, of which the cliffs were thrown down from time to time, as were those of Gian Greco, in Calabria, during the earthquake of 1783. The waves and currents would have continued their denuding action during the emergence of these islands, until at length, when the intervening channels were laid dry, and rivers began to flow, the deepening and widening of the valleys by rivers and land-floods would proceed in the same manner as in modern times in Calabria.†

Before a tract could be upraised to the height of several thousand feet above the level of the sea, the joint operation of running water and subterranean movements must greatly modify its physical geography; but when the action of the volcanic forces has been suspended, when a period of tranquillity succeeds, and the levels of the land remain fixed and stationary, the erosive power of water must soon be reduced to a state of comparative equilibrium. For

* Vol. II. p. 281. † Ibid.

this reason, a country that has been raised at a very remote period to a considerable height above the level of the sea may present nearly the same external configuration as one that has been more recently uplifted to the same height.

Migration of animals and plants. — The changes above described, which have been brought about by igneous and aqueous agency, cannot fail to strike the imagination, when we consider how recent in the calendar of nature is the epoch to which they are referred. But if we turn our thoughts to the organic world, we shall feel, perhaps, no less surprise at the great vicissitude which it has undergone during the same period.

We have seen that a large portion of Sicily has been converted from sea to land since the Mediterranean was peopled with the living species of testacea and zoophytes. The newly emerged surface, therefore, must, during this modern zoological epoch, have been inhabited for the first time by the terrestrial plants and animals which now abound in Sicily. It is fair to infer that the existing terrestrial species are, for the most part, of as high antiquity as the marine; and if this be the case, a large proportion of the plants and animals, now found in the tertiary districts in Sicily, must have inhabited the earth before the Newer Pliocene strata were raised above the waters. The plants of the flora of Sicily are common, almost without exception, to Italy or Africa, or some of the countries surrounding the Mediterranean; so that we may suppose the greater part of them to have migrated from pre-existing lands, just as the plants and animals of the Phlegræan fields have colonized Monte

Nuovo, since that mountain was thrown up in the sixteenth century.*

We are brought, therefore, to admit the curious result, that the flora and fauna of the Val di Noto, and some other mountainous regions of Sicily, are of higher antiquity than the country itself, having not only flourished before the lands were raised from the deep, but even before they were deposited beneath the waters. Such conclusions throw a new light on the adaptation of the attributes and migratory habits of animals and plants, to the changes which are unceasingly in progress in the inanimate world. It is clear that the duration of species is so great, that they are destined to outlive many important revolutions in the physical geography of the earth ; and hence those innumerable contrivances for enabling the subjects of the animal and vegetable creation to extend their range, the inhabitants of the land being often carried across the ocean, and the aquatic tribes over great continental spaces.† It is obviously expedient that the terrestrial and fluviatile species should not only be fitted for the rivers, valleys, plains, and mountains which exist at the era of their creation, but for others that are destined to be formed before the species shall become extinct ; and, in like manner, the marine species are not only made for the deep and shallow regions of the ocean existing at the time when they are called into being, but for tracts that may be submerged or

* Professor Viviani of Genoa informed me, that, considering the great extent of Sicily, it was remarkable that its flora produced scarcely any, *if any peculiar indigenous* species ; whereas there are several in Corsica, and some other Mediterranean islands.

† See book iii. chaps. v. vi. and vii.

variously altered in depth during the time that is allotted for their continuance on the globe.

Recapitulation. — I may now briefly recapitulate some of the most striking results deduced from the investigation of a single district where the Newer Pliocene strata are largely developed.

In the first place, we have seen reason to infer that a stratified mass of solid limestone, attaining sometimes a thickness of eight hundred feet and upwards, has been gradually deposited at the bottom of the sea, the imbedded fossil shells and corallines being almost all of recent species; yet these fossils are frequently in the state of mere casts, so that in appearance they correspond very closely to organic remains found in limestones of very ancient date.

2dly. In some localities the limestone above mentioned alternates with volcanic rocks, such as have been formed by submarine eruptions, recurring again and again at distant intervals of time.

3dly. Argillaceous and sandy deposits have also been produced during the same period, and their accumulation has also been accompanied by submarine eruptions. Masses of mixed sedimentary and igneous origin, at least two thousand feet in thickness, can thus be shown to have accumulated since the sea was peopled with the greater number of the aquatic species now living.

4thly. These masses of submarine origin have, since their formation, been raised to the height of two thousand or three thousand feet above the level of the sea, and this elevation implies an extraordinary modification in the state of the earth's crust at some unknown depth beneath the tract so upheaved.

5thly. This modification may possibly correspond

with the effects of what is usually called "plutonic action," or the agency of volcanic and other causes at considerable depths; in which case, the Newer Pliocene plutonic rocks, formed beneath Sicily, must be of great extent.

6thly. Considerable inequalities must have been caused on the surface of the new-raised lands during the emergence of the Newer Pliocene strata, by the action of tides, currents, and rivers, combined with the disturbing and dislocating force of the elevatory movements.

7thly. There are no features in the forms of the valleys and sea-cliffs thus recently produced which indicate the sudden rise of the strata to their present altitude, while there are some proofs of distinct and partial elevations at successive periods.

8thly. We may infer that the species of terrestrial and fluviatile animals and plants which now inhabit extensive districts, formed during the Newer Pliocene era, were in existence not only before the new strata were raised, but before their materials were brought together at the bottom of the sea.

CHAPTER X.

NEWER PLIOCENE FORMATIONS — MARINE AND VOLCANIC.

Tertiary formations of Campania — Comparison of the recorded changes in this region with those commemorated by geological monuments — Dikes of Somma — Parallelism of their opposite sides (p. 21.) — Age of the volcanic and associated rocks of Campania — Organic remains — No signs of diluvial waves — Marine Newer Pliocene strata chiefly seen in countries of earthquakes (p. 31.) — Illustrations from Chili — Peru — Parallel roads of Coquimbo — West Indies (p. 36.) — East Indian archipelago — Red Sea.

Tertiary Formations of Campania.

Comparison of recorded changes with those commemorated by geological monuments. — In the second volume I traced the various changes which the volcanic region of Naples is known to have undergone during the last two thousand years; and, imperfect as are our historical records, the aggregate effect of igneous and aqueous agency, during that period, was shown to be far from insignificant. The rise of the modern cone of Vesuvius, since the year 79, was the most memorable event during those twenty centuries; but, in addition to this remarkable phenomenon, I enumerated the production of several new minor cones in Ischia, and of the Monte Nuovo, in the year 1538. The flowing also of lava currents upon the land and along the bottom of the

sea was described,—the showering down of volcanic sand, pumice, and scoriæ, in such abundance that whole cities were buried,—the filling up or shoaling of certain tracts of the sea, and the transportation of tufaceous sediment by rivers and land floods. I also explained the evidence in proof of a permanent alteration of the relative levels of the land and sea in several places, and of the same tract having, near Puzzuoli, been alternately upheaved and depressed to the amount of more than twenty feet. In connection with these convulsions, I pointed out that, on the shores of the Bay of Baiæ, there are recent tufaceous strata filled with fabricated articles, mingled with marine shells. It was also shown that the sea has been making gradual advances upon the coast, not only sweeping away the soft tuffs of the Bay of Baiæ, but excavating precipitous cliffs, where the hard Ischian and Vesuvian lavas have flowed down into the deep.

These events, it may be objected, although interesting, are the results of operations on a very inferior scale to those indicated by geological monuments. When we examine this same region, it will be said we find that the ancient cone of Vesuvius, called Somma, is larger than the modern cone, and is intersected by a greater number of dikes,—the hills of unknown antiquity, such as Astroni, the Solfatara, and Monte Barbaro, formed by separate eruptions, in different parts of the Phlegræan fields, far outnumber those of similar origin, which are recorded to have been thrown up within the historical era. In place of modern tuffs of slight thickness, and single flows of lava, we find, amongst the older formations, hills from 500 to more than 2000 feet in height, composed of an immense

series of tufaceous strata, alternating with distinct lava currents. We have evidence that in the lapse of past ages, districts, not merely a few miles square, were upraised to the height of twenty or thirty feet above their former level, but that extensive and mountainous countries were uplifted to an elevation of more than 1000 feet, and at some points more than 2000 feet, above the level of the sea.

These and similar objections are made by those who compare the modern effects of igneous and aqueous causes, not with a part but with the whole results of the same agency in antecedent ages. Thus viewed in the aggregate, the leading geological features of each district must always appear to be on a colossal scale, just as a large edifice may seem an effort of superhuman power, until we reflect on the innumerable minute parts of which it is composed, the number of the builders, and the time required to raise it. A mountain mass, so long as the imagination is occupied in contemplating the gigantic whole, must appear the work of extraordinary causes; but when the separate portions of which it is made up are carefully studied, they are seen to have been formed successively; and the dimensions of each part, considered singly, are soon recognized to be comparatively insignificant, so that it appears no longer extravagant to liken them to the recorded effects of ordinary causes.

Difference in the composition of Somma and Vesuvius.

As no traditional accounts have been handed down to us of the eruptions of the ancient Vesuvius, from the times of the earliest Greek colonists, the volcano must have been dormant for many centuries, perhaps

for thousands of years, previous to the great eruption in the reign of Titus. But it will be shown hereafter that there are sufficient grounds for presuming this mountain, and the other igneous products of Campania, to have been produced during the Newer Pliocene period.

We have seen that the ancient and modern cones of Vesuvius were each a counterpart of the other in structure*; and I may now remark that the principal point of difference consists in the greater abundance in the older cone of fragments of altered sedimentary rocks ejected during eruptions. We may easily conceive that the first explosions would act with the greatest violence, rending and shattering whatever solid masses obstructed the escape of lava and the accompanying gases, so that great heaps of ejected pieces of rock would naturally occur in the tufaceous breccias formed by the earliest eruptions. But when a passage had once been opened and an habitual vent established, the materials thrown out would consist of liquid lava, which would take the form of sand and scoriæ, or of angular fragments of such solid lavas as may have choked up the vent.

Among the fragments which abound in the tufaceous breccias of Somma, none are more common than a saccharoid dolomite, supposed to have been derived from an ordinary limestone altered by heat and volcanic vapours.

Carbonate of lime enters into the composition of so many of the simple minerals found in Somma, that M. Mitscherlich, with much probability, ascribes their

* Vol. II. p. 140.

great variety to the action of the volcanic heat on subjacent masses of limestone.

Dikes of Somma.—The dikes seen in the great escarpment which Somma presents towards the modern cone of Vesuvius are very numerous. They are for the most part vertical, and traverse at right angles the beds of lava, scoriæ, volcanic breccia, and sand, of which the ancient cone is composed. They project in relief several inches, or sometimes feet, from the face of the cliff, like the dikes of Etna already described (see Fig. 82.), being, like them, extremely compact, and less destructible than the intersected tuffs and porous lavas. In vertical extent they vary from a few yards to 500 feet, and in breadth from one to twelve feet. Many of them cut all the inclined beds in the escarpment of Somma from top to bottom, others stop short before they ascend above half way, and a few terminate at both ends, either in a point or abruptly. In mineral composition they scarcely differ from the lavas of Somma, the rock consisting of a base of leucite and augite, through which large crystals of augite and some of leucite are scattered.* Examples are not rare of one dike cutting through another, and in one instance a shift or fault is seen at the point of intersection. I observed before, when speaking of the dikes of the modern cone of Vesuvius, that they must have been produced by the filling up of open fissures by liquid lava.† In some examples, however, the rents seem to have been filled laterally.

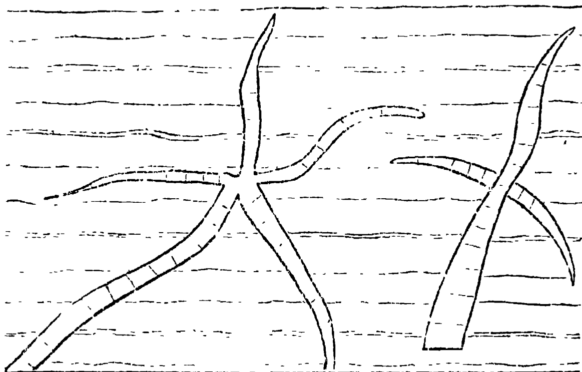
The reader will remember the description before

* Consult the valuable memoir of M. L. A. Necker, Mém. de la Soc. de Phys. et d'Hist. Nat. de Génève, tome ii. part i., Nov. 1822.

† Vol. II. p. 138.

given of the manner in which the plain of Jerocarne, in Calabria, was fissured by the earthquake of 1783, so that the academicians compared it to the cracks in a broken pane of glass.* If we suppose the side walls of the ancient crater of Vesuvius to have been

Fig. 89.



Dikes or veins at the Punta del Nasone on Somma

cracked in like manner, and the lava to have entered the rents and become consolidated, we can explain the singular form of the veins figured in the accompanying wood-cut.†

Parallelism of their opposite sides. — Nothing is more remarkable than the parallelism of the opposite sides of the dikes, which usually correspond with as much regularity as the two opposite faces of a wall of masonry. This character appears at first the more inexplicable, when we consider how jagged and uneven are the rents caused by earthquakes in masses of heterogeneous composition like those composing the

* See Vol. II. p. 266. Fig. 84.

† From a drawing of M. Necker, in Mém. before cited.

cone of Somma; but M. Necker has offered an ingenious and, I think, satisfactory explanation of the phenomenon. He refers us to Sir W. Hamilton's account of an eruption of Vesuvius in the year 1779, who records the following facts:—"The lavas, when they either boiled over the crater, or broke out from the conical parts of the volcano, constantly formed channels as regular as if they had been cut by art, down the steep part of the mountain; and, whilst in a state of perfect fusion, continued their course in those channels, which were sometimes full to the brim, and at other times more or less so, according to the quantity of matter in motion.

"These channels, upon examination after an eruption, I have found to be in general from two to five or six feet wide, and seven or eight feet deep. They were often hid from the sight by a quantity of scoriæ that had formed a crust over them; and the lava, having been conveyed in a covered way for some yards, came out fresh again into an open channel. After an eruption I have walked in some of those subterraneous or covered galleries, which were exceedingly curious, the sides, top, and bottom, *being worn perfectly smooth and even* in most parts, by the violence of the currents of the red-hot lavas, which they had conveyed for many weeks successively."

In another place, in the same memoir, he describes the liquid and red-hot matter as being received "into a regular channel, raised upon a sort of wall of scoriæ and cinders, almost perpendicularly, of about the height of eight or ten feet, resembling much an ancient aqueduct."*

Now, if the lava in these instances had not run out

* Phil. Trans., vol. lxx. 1780.

from the covered channel, in consequence of the declivity whereon it was placed—if, instead of the space being left empty, the lava had been retained within until it cooled and consolidated, it would then have constituted a small dike with parallel sides. But the walls of a vertical fissure through which lava has ascended in its way to a volcanic vent, must have been exposed to the same erosion as the four sides of the channels before adverted to. The prolonged and uniform friction of the heavy fluid, as it is forced and made to flow upwards, cannot fail to wear and smooth down the surfaces on which it rubs, and the intense heat must melt all such masses as project and obstruct the passage of the incandescent fluid.

I do not mean to assert that the sides of fissures caused by earthquakes are never smooth and parallel, but they are usually uneven, and are often seen to have been so where volcanic or *trap* dikes are as regular in shape as those of Somma. The solution, therefore, of this problem, in reference to the modern dikes, is most interesting, as being of very general application in geology.

Varieties in their texture. — Having explained the origin of the parallelism of the sides of a dike, we have next to consider the difference of its texture at the edges and in the middle. Towards the centre, observes M. Necker, the rock is larger grained, the component elements being in a far more crystalline state; while at the edge the lava is sometimes vitreous, and always finer grained. A thin parting band, approaching in its character to pitchstone, occasionally intervenes on the contact of the vertical dike and intersected beds. M. Necker mentions one of these at the place called Primo Monte, in the Atrio del Cavallo; I saw three

or four others in different parts of the great escarpment. These phenomena are in perfect harmony with the results of the experiments of Sir James Hall and Mr. Gregory Watt, which have shown that a glassy texture is the effect of sudden cooling, and that, on the contrary, a crystalline grain is produced where fused minerals are allowed to consolidate slowly and tranquilly under high pressure.

It is evident that the central portion of the lava in a fissure would, during consolidation, part with its heat more slowly than the sides, although the contrast of circumstances would not be so great as when we compare the lava at the bottom and at the surface of a current flowing in the open air. In this case the uppermost part, where it has been in contact with the atmosphere, and where refrigeration has been most rapid, is always found to consist of scoriform, vitreous, and porous lava, while at a greater depth the mass assumes a more lithoidal structure, and then becomes more and more stony as we descend, until at length we are able to recognize with a magnifying glass the simple minerals of which the rock is composed. On penetrating still deeper, we can detect the constituent parts by the naked eye, and in the Vesuvian currents distinct crystals of augite and leucite become apparent.

The same phenomenon, observes M. Necker, may readily be exhibited on a smaller scale, if we detach a piece of liquid lava from a moving current. The fragment cools instantly, and we find the surface covered with a vitreous coat, while the interior, although extremely fine grained, has a more stony appearance.

It must, however, be observed, that although the

lateral portions of the dikes are finer grained than the central, yet the vitreous parting layer before alluded to is extremely rare. This may, perhaps, be accounted for, as the above-mentioned author suggests, by the great heat which the walls of a fissure may acquire before the fluid mass begins to consolidate, in which case the lava, even at the sides, would cool very slowly. Some fissures, also, may be filled from above; and in this case the refrigeration at the sides would be more rapid than when the melted matter flowed upwards from the volcanic foci, in an intensely heated state.

The rock composing the dikes of Somma is far more compact than that of ordinary lava, for the pressure of a column of melted matter in a fissure greatly exceeds that in an ordinary stream of lava; and pressure checks the expansion of those gases which give rise to vesicles in lava.

There is a tendency in almost all the Vesuvian dikes to divide into horizontal prisms *, a phenomenon in accordance with the formation of vertical columns in horizontal beds of lava; for in both cases the divisions which give rise to the prismatic structure are at right angles to the cooling surfaces.

Minor cones of the Phlegræan Fields. — In the volcanic district of Naples there are a great number of conical hills with craters on their summits, which have evidently been produced by one or more explosions, like that which threw up the Monte Nuovo in 1538. They are composed of trachytic tuff, which is loose and incoherent, both in the hills and, to a certain depth, in the plains around their base, but which is in-

* See Fig. 89. p. 21.

durated below. It is suggested by Mr. Scrope, that this difference may be owing to the circumstance of the volcanic vents having burst out in a shallow sea, as was the case with Monte Nuovo, where there is a similar foundation of hard tuff, under a covering of loose lapilli. The subaqueous part may have become solid by an aggregative process like that which takes place in the setting of mortar, while the rest of the ejections, having accumulated on dry land when the cone was raised above the water, may have remained in a loose state.*

Age of the volcanic and associated rocks of Campania. — If we inquire into the evidence derivable from organic remains, respecting the age of the volcanic rocks of Campania, we find reason to conclude that such parts as do not belong to the Recent are referrible to the Newer Pliocene period. In the solid tuff quarried out of the hills immediately behind Naples, are found recent shells of the genera Ostrea, Cardium, Buccinum, and Patella, all referrible to species now living in the Mediterranean.† In the centre of Ischia the lofty hill called Epomeo, or San Nichola, is composed of greenish indurated tuff of a prodigious thickness, interstratified in some parts with argillaceous marl, and here and there with great streams of indurated lava. Visconti ascertained by trigonometrical measurement that this mountain was 2605 feet above the level of the sea. In mineral composition and in form, as seen from many points of view, it resembles the hill to the north of Naples on the summit of which stands the convent of Camaldoli, which is 1643 feet in height. I collected in 1828 many recent marine shells from beds

* Geol. Trans., vol. ii. part iii. p. 351. Second Series.

† Scrope, ibid.

of clay and tuff, not far from the summit of Epomeo, about 2000 feet above the level of the sea, as also at another place, about 100 feet below the first, on the southern declivity of the mountain, and others still lower, not far above the town of Moropano. At Casamicciol, and several places near the sea-shore, shells have long been observed in stratified tuff and clay. From these various points I obtained, during a short excursion in Ischia, twenty-eight species of shells, all of which, with one exception, were identified by M. Deshayes with recent species.*

It is clear, therefore, that the great mass of Epomeo was not only raised to its present height above the level of the sea, but was also *formed*, since the Mediterranean was inhabited by the existing species of testacea.

In the Ischian tuffs we find pumice, lapilli, angular fragments of trachytic lava, and other products of igneous ejections, interstratified with some deposits of clay free from any intermixture of volcanic matter. These clays might have resulted from the decomposition of felspathic lava which abounds in Ischia, the materials having been transported by rivers and marine currents, and spread over the bottom of the sea where testacea were living. All these submarine tuffs, lavas, and clays of Campania, very much resemble those around the base of Etna, and in parts of the Val di Noto before described.

External configuration of the country, how caused. — When once we have satisfied ourselves by inspection of the marine shells imbedded in tuffs at high elevations, that a mass of land like the island of Ischia has been

* See the list of these shells, Appendix II. first ed.

raised from beneath the waters of the sea to its present height, we are prepared to find signs of the denuding action of the waves impressed upon the outward form of the island, especially if we conceive the upheaving force to have acted by successive movements. Let us suppose the low contiguous island of Procida to be raised by degrees until it attains the height of Ischia; we should in that case expect the steep cliffs which now face Misenum to be carried upwards, and to become precipices near the summit of the central mountain. Such, perhaps, may have been the origin of those precipices which appear on the north and south sides of the ridge which forms the summit of Epomeo in Ischia. The northern escarpment is about 1000 feet in height, rising from the hollow called the Cavo delle Neve, above the village of Panella. The abrupt manner in which the horizontal tuffs are there cut off, in the face of the cliff, is such as the action of the sea, working on soft materials, might easily have produced, undermining and removing a great portion of the mass. A heap of shingle which lies at the base of a steep declivity on the flanks of Epomeo, between the Cavo delle Neve and Panella, may once, perhaps, have been a sea-beach, for it certainly could not have been brought to the spot by any existing torrents.

There is no difficulty in conceiving that if a large tract of the bed of the sea near Ischia should now be gradually upheaved during the continuance of volcanic agency, this newly raised land might present a counterpart to the Phlegræan Fields before described. Masses of alternating lava and tuff, the products of submarine eruptions, might on their emergence become hills and islands; the level intervening plains might afterwards appear, covered partly by the ashes

drifted and deposited by water, and partly by those which would fall after the laying dry of the tract. The last features imparted to the physical geography would be derived from such eruptions in the open air as those of Monte Nuovo and the minor cones of Ischia.

No signs of diluvial waves.—Such a conversion of a large tract of sea into land might possibly take place, while the surface of the contiguous country underwent but slight modification. No great wave was caused by the permanent rise of the coast near Puzzuoli in the year 1538, because the upheaving operation appears to have been effected by a succession of minor shocks.* A series of such movements, therefore, might produce an island like Ischia without throwing a diluvial rush of waters upon low parts of the neighbouring continent. The advocates of paroxysmal elevations may, perhaps, contend that the rise of Ischia must have been anterior to the birth of all the cones of loose scoriæ scattered over the Phlegræan Fields; for, according to them, the sudden rise of marine strata causes inundations which devastate adjoining continents. But the absence of any signs of such floods in the volcanic region of Campania does not appear to me to warrant the conclusion, either that Ischia was raised previously to the production of the volcanic cones, or that it may not have been rising during the whole period of their formation.

We learn from the study of the mutations now in progress, that one part of the earth's surface may, for an indefinite period, be the scene of continued change, while another, in the immediate vicinity, remains sta-

* See Vol. II. p. 312.

tionary. We need go no farther than our own country to illustrate this principle; for, reasoning from what has taken place in the last ten centuries, we must anticipate that in the course of the next four thousand or five thousand years, a long strip of land, skirting the line of our eastern coast, will be devoured by the ocean, while part of the interior, immediately adjacent, will remain at rest and entirely undisturbed. The analogy holds true in regions where the volcanic fires are at work; for part of the Philosopher's Tower on Etna has stood for the last two thousand years, at the height of more than nine thousand feet above the sea, between the foot of the highest cone and the edge of the precipice which overhangs the Val del Bove, whilst large tracts of the surrounding district have been the scenes of tremendous convulsions. The great cone above has more than once been destroyed, and again renewed; the earth has sunk down in the neighbouring Cisterna *; the cones of 1811 and 1819 have been thrown up, on the ledge of rock below, pouring out of their craters two copious streams of lava; the watery deluge of 1755, descending from the desert region into the Val del Bove, has rolled vast heaps of rocky fragments towards the sea; fissures, several miles in length, have opened on the flanks of Etna; towns and villages have been laid in ruins by earthquakes, or buried under lava and ashes; — yet the tower has stood, as if placed there to commemorate the stability of one part of the earth's surface, while others in immediate proximity have been subject to most wonderful vicissitudes.

In concluding what I have to say of the marine and

* See Vol. III. p. 448.

volcanic formations of the Newer Pliocene period, I may notice the highly interesting fact, that the marine strata of this era have been found at great elevations, chiefly in those countries where earthquakes have occurred during the historical ages. On the other hand, it is a still more striking fact, that there is no example of any extensive maritime district, now habitually agitated by violent earthquakes, which has not, when carefully investigated, yielded traces of marine strata, either of Recent or Newer Pliocene eras, at a considerable height above the sea.

Chili—Conception Bay.—In illustration of the above remarks, I may mention that on the western coast of South America marine deposits occur, containing precisely the same shells as are now living in the Pacific. In Chili, for example, as before stated, micaceous sand, containing the fossil remains of such species as now inhabit the Bay of Conception, are found at the height of from 1000 to 1500 feet above the level of the ocean.* It is impossible to say how much of this rise may have taken place during the *Recent* period. One earthquake appears to have raised this part of the Chilian coast, in 1750, to the height of at least twenty-five feet above its former level. If we could suppose a series of such shocks to occur, one in every century, only 6000 years would be required to uplift the coast 1500 feet. But we have no data for inferring that so great a quantity of elevation has taken place in that space of time; and although there is no evidence that the micaceous sand may not belong to the Recent period, I think it more probable that it was deposited during the Newer Pliocene period.

* Vol. II. p. 300.

Peru.—I have been informed by Mr. A. Cruckshanks, a naturalist who resided for several years in South America, that in the valley of Lima, or Rimao, where the subterranean movements have been so violent in recent times, there are indications not only of a considerable rise of the land, but of that rise having resulted from *successive* movements. Distinct lines of ancient sea-cliffs have been observed at various heights, at the base of which the hard rocks of greenstone are hollowed out into precisely those forms which they now assume between high and low water mark on the shores of the Pacific. Immediately below these water-worn lines are ancient beaches strewed with rounded blocks. One of these cliffs appears in the hill behind Baños del Pujio, about seven hundred feet above the level of the sea, and two hundred above the contiguous valley. Another occurs at Amancaes, at the height of perhaps two hundred feet above the sea; and others at intermediate elevations.

Parallel Roads of Coquimbo.—We can hardly doubt that the parallel roads of Coquimbo, in Chili, described by Captain Hall, owe their origin to similar causes. These roads, or shelves, occur in a valley six or seven miles wide, which descends from the Andes to the Pacific. Their general width is from twenty to fifty yards, but they are, at some places, half a mile broad. They are so disposed as to present exact counterparts of one another, at the same level, on opposite sides of the valley. There are three distinctly characterized sets; the upper one lies about three or four hundred feet above the level of the sea; the next twenty yards lower; and the lowest about ten yards still lower. Each resembles a shingle beach, being formed entirely of loose materials, principally water-worn rounded stones,

from the size of a nut to that of a man's head. The stones are principally granite and gneiss, with masses of schistus, whinstone, and quartz, mixed indiscriminately, and all bearing marks of having been worn by attrition under water.*

The theory proposed by Captain Hall to explain these appearances is the same as that which had been adopted to account for the analogous parallel roads of Glen Roy in Scotland.† The valley is supposed to have been a lake, the waters of which stood, originally, at the level of the highest road, until a flat beach was produced. A portion of the barrier was then broken down, which allowed the lake to discharge part of its waters into the sea, and, consequently, to fall to the second level; and so on successively till the whole embankment was washed away, and the valley left as we now see it.

As I did not feel satisfied with this explanation, I applied to my friend Captain Hall for additional details, and he immediately sent me his original manuscript notes, requesting me to make free use of them. In them I find the following interesting passages, omitted in his printed account:—"The valley is completely open towards the sea; if the roads, therefore, are the beaches of an ancient lake, it is difficult to imagine a catastrophe sufficiently violent to carry away the barrier, which should not at the same time obliterate all traces of the beaches. I find it difficult also to account for the water-worn character of all the stones, for they have the appearance of having travelled over a great distance, being well rounded and dressed. They

* Captain Hall's South America, vol. ii. p. 9.

† See Sir T. D. Lauder, Ed. Roy. Soc. Trans., vol. ix.; and Dr. Macculloch, Geol. Trans., 1st Series, vol. iv. p. 314.

are in immense quantity too, and much more than one could expect to find on the beach of any lake, and *seem more properly to belong to the ocean.*"

I had entertained a strong suspicion, before reading these notes, that the beaches were formed by the waves of the Pacific, and not by the waters of a lake; in other words, that they bear testimony to the successive rise of the land, not to the repeated fall of the waters of a lake. M. Boblaye has discovered four or five distinct ranges of ancient sea-cliffs, one above the other, at various heights, in the Morea, which attest that that country has been upheaved at as many successive periods. He found inland terraces or beaches, covered with shells, at the base of precipices worn like the modern sea-cliffs by the waves, and having, like them, many caverns and lithodomous perforations in the hard limestone.*

Near the northern gate of the town of St. Mihiel, south of Verdun, in France, I have examined a series of markings on the face of the limestone cliffs, much resembling some of those described by M. Boblaye. There are three and sometimes four distinct horizontal grooves, which have been scooped out of a white semi-crystalline rock, or marble, of the oolitic period. This ancient cliff, which is near the right bank of the Meuse, is in part broken into a number of detached rocks, the upper parts of which present in some cases precipitous sides towards all points of the compass, round which the grooves pass in a circular course, just as if the summit of a rocky islet had been worn by the waves.†

* Journ. de Géol., No. x. Feb. 1831; Bull. de la Soc. Géol. de France, tom. ii. p. 236.

† I have no data for speculating on the period at which these cliffs may have emerged from the sea. I was directed to the spot,

Captain Bayfield, in his survey of the coast of the Gulf of St. Lawrence, traced in several places, especially in the Mingan Islands, a succession of shingle beaches, the most distant from the shore being sixty feet above the level of the highest tides. He also observed water-worn pillars of limestone accompanying these beaches, which bear evidence of having been worn and scooped out at different periods; the marks of the successive action of the water agreeing in level with the successive ridges of limestone shingle. The drawings of the pillars, made to illustrate his memoir, convince me that they are counterparts of the worn rocks which I have seen at St. Mihiel.*

If there exist lines of parallel upraised cliffs, we ought to find parallel lines of elevated beaches on those coasts where the rocks are of a nature to retain for a length of time the marks imprinted on their surface. We may expect such indications to be peculiarly manifest in countries where the subterranean force has been in activity within comparatively modern times, and it is there that the hypothesis of paroxysmal elevations, and the instantaneous rise of mountain-chains, should first have been put to the test, before it was too hastily embraced and extended.

which I visited in June, 1833, by M. Deshayes; and I stated in the second edition, on his authority, that the worn rocks were eaten into by marine lithodomous shells, but I was unable to discover any of these; and I believe that the fossils of the genus Saxicava, which M. Deshayes procured from this place, were of the age of the corals of the limestone, not of the date of the excavation of the grooves. The fossil corals of this formation (coral rag) frequently contain lithodomous shells, which seem to have pierced the zoophytes while they were still growing in the sea.

* Proceedings of Geol. Soc., No. 33. p. 5.

West Indian Archipelago. — According to the sketch given by Maclure of the geology of the Leeward Islands, the western range consists in great part of formations of the most modern period.* It will be remembered, that many parts of this region have been subject to violent earthquakes; that in St. Vincent's and Guadaloupe there are active volcanos, and in some of the other islands boiling springs and solfataras. In St. Eustatia there is a marine deposit, estimated at 1500 feet in thickness, consisting of coral limestone alternating with beds of shells, of which the species are, according to Maclure, the same as those now found in the sea. These strata dip to the south-west, at an angle of about 45°, and both rest upon, and are covered by, cinders, pumice, and volcanic substances. Part of the madreporic rock has been converted into silex and calcedony, and is, in some parts, associated with crystalline gypsum. Alternations of coralline formations with prismatic lava and different volcanic substances also occur in Dominica and St. Christopher's; and the American naturalist remarks, that as every lava-current which runs into the sea in this archipelago is liable to be covered with corals and shells, and these again with lava, we may suppose an indefinite repetition of such alternations to constitute the foundation of each island.

I do not question the accuracy of the opinion, that the fossil shells and corals of these formations are of recent species; for there are specimens of limestone in the Museum of the Jardin du Roi at Paris, from the West Indies, in which the imbedded shells are all or nearly all identical with those now living. Part of

* Quart. Journ. of Sci., vol. v. p. 311.

this limestone is soft, but some of the specimens are very compact and crystalline, and contain only the casts of shells. Of thirty species examined by M. Deshayes from this rock, twenty-eight were decidedly recent.

Honduras. — Shells sent from some of the recent strata of Jamaica, and many from the nearest adjoining continent of the Honduras, may be seen in the British Museum, and are identified with species now living in the West Indian seas.

East Indian Archipelago. — We have seen that the Indian Ocean is one of the principal theatres of volcanic disturbance; it is to be expected, therefore, that future researches in this quarter of the globe will bring to light some of the most striking examples of marine strata upraised to great heights during comparatively modern periods.

From the observations of Dr. Jack, it appears that in the island of Pulo Nias, off the west coast of Sumatra, masses of corals of recent species can be traced from the level of the sea far into the interior, where they form considerable hills. Large shells of the Chama gigas (*Tridacna*, Lamk.) are scattered over the face of the country, just as they occur on the present reefs. These fossils are in such a state of preservation as to be collected by the inhabitants for the purpose of being cut into rings for the arms and wrists.*

Madeira. — The island of Madeira is placed between the Azores and Canaries, in both of which groups there are active volcanos; and Madeira itself was violently shaken by earthquakes during the last century.

* Geol. Trans., Second Series, vol. i. part ii. p. 397.

It consists in great part of volcanic tuffs and porous lava, intersected in some places, as at the Brazen Head, by vertical dikes of compact lava.* Some of the marine fossil shells, procured by Mr. Bowdich from this island, are referrible to recent species.

These examples may suffice for the present, and lead us to anticipate with confidence, that in almost all countries where changes of level have taken place in our own times, the geologist will find monuments of a prolonged series of convulsions during the Recent and Newer Pliocene periods. Exceptions may no doubt occur where a particular line of coast is sinking down; yet even here we may presume, from what we know of the irregular action of the subterranean forces, that some cases of partial elevation will have been caused by occasional oscillations of level, so that modern subaqueous formations will, here and there, have been brought up to view.

I shall conclude by enumerating some exceptions to the rule above illustrated, — instances of elevation where no great earthquakes have been recently experienced.

Scandinavia. — The first and most important is that of Sweden, before described in detail.† This country, although free from convulsions, was shown to be the theatre of unceasing changes in the relative level of land and sea. We accordingly discover in it deposits of sand, marl, and clay, several hundred feet in thickness, and containing recent species of marine shells raised to the height of 200 feet, and even in Norway 400 feet above the sea, and extending at some points far into the interior.

* MS. of Captain B. Hall.

† Book ii. chap. xvii.

Grosœil, near Nice. — At a spot called Grosœil, near Nice, east of the Bay of Villefranche, in the peninsula of St. Hospice, a remarkable bed of fine sand occurs at an elevation of about fifty feet above the sea.* This sand rests on inclined secondary rocks, and is filled with the remains of marine species, all identical with those now inhabiting the neighbouring sea. No less than two hundred species of shells, and several crustacea and echini, have been obtained by M. Risso, in a high state of preservation, although mingled with broken shells. The winds have blown up large heaps of similar sand to considerable heights, upon ledges of the steep coast farther westward; but the position of the deposit at Grosœil cannot be referred to such agency, for among the shells may be seen the large Murex Triton, Linn., and a species of Cassis, weighing a pound and a half.

West of England.—The proofs lately brought to light of analogous elevations on our western shores, in Caernarvonshire and Lancashire, during some comparatively modern period, were before pointed out†; but the data are as yet exceedingly incomplete.

Western borders of the Red Sea. — Another exception may be alluded to, for which we are indebted to the researches of Mr. James Burton. On the western shores of the Arabian Gulf, about half way between Suez and Kosire, in the 28th degree of north latitude, a formation of white limestone and calcareous sand is seen, reaching the height of 200 feet above the sea. It is replete with fossil shells, all of recent species, which are in a beautiful state of preservation, many of

* I examined this locality, in company with Mr. Murchison, in 1828.

† See description of the Map, Vol. I. p. 210.

them retaining their colour.* The volcano of Gabel Tor, situate at the entrance of the Arabian Gulf, is the nearest volcanic region known to me at present.

Timor.—In the island of Timor, which approaches very near to the great volcanic band traced by Von Buch†, M. Péron mentions the occurrence of corals and marine shells, apparently of recent species‡; and Dr. Fitton, in his account of Capt. King's collection of rocks from Australia, mentions a calcareous sandstone and breccia, at the height of several hundred feet above the sea, on many parts of the Australian coast.§ Future observations must decide whether these formations belong to the newest tertiary era, as conjectured. Some of the above examples certainly afford proofs of elevation, since the commencement of the Newer Pliocene period, to considerable heights, in countries far from the existing theatres of volcanic action; yet in these instances the upraised deposits containing recent shells appear in general to be confined to the coast, and not to enter largely, like those of Sicily, into the structure of mountains in the interior.

But the reader must not infer, from the facts above detailed, that marine strata of the Newer Pliocene period have been produced almost exclusively in countries of earthquakes, or where changes of level are taking place, as in Sweden. If our illustrations have been drawn chiefly from modern volcanic regions, it is

* These fossils are now in the museum of Mr. Greenough, in London, and duplicates, presented by him, in the cabinets of the Geological Society. A list of them was given in App. II., first edition.

† See Map, Vol. II.

‡ Voy. découv. des Terres Australes, vol. ii. pp. 165. 183.

§ App. to Captain P. King's Australia.

simply because these formations have been made visible in those districts only where the conversion of sea into land has taken place in times comparatively modern. Other continents have, during the Newer Pliocene period, suffered degradation, and rivers and currents have deposited sediment in other seas; but the new strata remain concealed wherever no subsequent alterations of level have taken place.

Yet, to a certain limited extent, the growth of new subaqueous deposits may have been greatest where igneous and aqueous causes have co-operated. It is there that the degradation of land is most rapid, and it is there only that materials ejected from below, by volcanic explosions, are added to the sediment transported by running water.*

* See Book ii. chap. xv.; and Book iii. chap. xviii.

CHAPTER XI.

NEWER PLIOCENE FORMATIONS — FRESH-WATER AND ALLUVIAL.

Newer Pliocene fresh-water formations — Valley of the Elsa — Travertins of Rome — Loess of the Valley of the Rhine — Contains recent terrestrial and aquatic shells — Its origin — Osseous breccias of the Newer Pliocene era (p. 51.) — Fossil bones of Marsupial animals in Australian caves — Newer Pliocene alluviums (p. 57.) — European alluviums chiefly tertiary — Erratic blocks of the Alps — Theory of their transportation by ice.

Fresh-water Formations.—In this chapter I shall treat of the fresh-water formations, and of the cave breccias and alluviums of the Newer Pliocene period.

In regard to the first of these, they must have been formed, in greater or less quantity, in nearly all the existing lakes of the world; in those, at least, of which the basins were formed before the earth was tenanted, by man. If the great lakes of North America originated before that era, the sedimentary strata deposited therein, in the ages immediately antecedent, would, according to the terms of our definition, belong to the Newer Pliocene period.

Valley of the Elsa.—As an example of the strata of this age, which have been exposed to view in consequence of the drainage of a lake, I may mention those of the valley of the Elsa, in Tuscany, between Florence and Sienna, where we meet with fresh-water

marls and travertins full of shells, belonging to species which now live in the lakes and rivers of Italy. Valleys several hundred feet deep have been excavated through the lacustrine beds, and the ancient town of Colle stands on a hill composed of them. The subjacent formation consists of marine Subapennine beds, in which more than half the shells are of recent species. The fresh-water shells which I collected near Colle are in a very perfect state, and the colours of the Neritinæ are peculiarly brilliant.*

Travertins of Rome. — Many of the travertins and calcareous tufas which cap the hills of Rome may also belong to the same period. The terrestrial shells inclosed in these masses are of the same species as those now abounding in the gardens of Rome, and the accompanying aquatic shells are such as are found in the streams and lakes of the Campagna. On Mount Aventine, the Vatican, and the Capitol, we find abundance of vegetable matter, principally reeds, encrusted with calcareous tufa, and intermixed with volcanic sand and pumice. The tusk of a mammoth has been procured from this formation, filled in the interior with solid travertin, wherein sparkling crystals of augite are interspersed, so that the bone has all the appearance of having been extracted from a hard crystalline rock.†

These Roman tufas and travertins repose partly on marine tertiary strata, belonging, perhaps, to the Older Pliocene era, and partly on volcanic tuff of a still later

* The following six pieces, all of which now inhabit Italy, were identified by M. Deshayes: — *Paludina impura, Neritina fluviatilis, Succinea amphibia, Limnea auricularis, L. pereger.*, and *Planorbis carinatus.*

† This fossil was shown me by Signor Riccioli at Rome.

date. They must have been formed in small lakes and marshes, which existed before the excavation of the valleys which divide the seven hills of Rome, and they must originally have occupied the lowest hollows of the country as it then existed; whereas now we find them placed upon the summit of hills about 200 feet above the alluvial plain of the Tiber. We know that this river has flowed nearly in its present channel ever since the building of Rome, and that scarcely any changes in the geographical features of the country have taken place since that era.

When the marine tertiary strata of this district were formed, those of Monte Mario for example, the Mediterranean was already inhabited by a large proportion of the existing species of testacea. At a subsequent period, volcanic eruptions occurred, and tuffs were superimposed. The marine formation then emerged from the deep, and supported lakes wherein the freshwater groups above described slowly accumulated, at a time when the mammoth inhabited the country. The valley of the Tiber was afterwards excavated, and the adjoining hills assumed their present shape; and then a long interval may, perhaps, have elapsed before the first human settlers arrived. Thus we have evidence of a chain of events, all regarded by the geologist as among the most recent, but which, nevertheless, may have preceded, for a long series of ages, a very remote era in the history of nations.

*Loess of the valley of the Rhine.**— A remarkable

* Since the publication of the octavo edition, I have had opportunities of re-examining the loess in the country between Cologne and Heidelberg, especially near Andernach, and of studying it in several parts of Baden, Darmstadt, Wurtemberg, and Nassau. The details of these observations have been given

deposit of calcareous loam, containing land and fresh-water shells of recent species, occurs here and there, in detached patches, throughout the valley of the Rhine, between Basle and Cologne, and on the flanks of the hills bordering the great valley. This deposit is provincially termed "loess" by the Germans, and in Alsace, "lehm."

According to M. Leonhard, the loess at Heidelberg consists chiefly of argillaceous matter, combined with a sixth part of carbonate of lime, and a sixth of quartzose and micaceous sand. It may be described as a pulverulent loam, of a dirty yellowish-grey colour, often containing calcareous sandy concretions or nodules, rarely exceeding the size of a man's head. Its entire thickness, in some places, amounts to between 200 and 300 feet; yet there are often no signs of stratification in the mass, except here and there at the bottom, where there is occasionally a slight intermixture of drifted materials derived from subjacent rocks.

I am informed by M. Studer, that the loess does not extend into Switzerland, but the Kaiserstuhl, a group of volcanic hills, standing almost in the middle of the plain of the Rhine, south of Strasburg, is covered with it to a great height; and I have seen it in large masses near the base of the Vosges, on the left side of the plain of the Rhine, near Strasburg, and on the right side, at the base of the mountains of the Black Forest. It extends also far into Wurtemberg, up the valley of

in a memoir read to the Geological Society in May, 1834, when I explained at length my reasons for changing and modifying some opinions formerly expressed in regard to the origin of the Löss, and its relations to the volcanic formations of the Lower Eifel.

the Neckar, and from Frankfort, up the valley of the Mayne, to above Dettelbach. In Nassau it is seen at Limburg, in the valley of the Lahn;[5] and in Darmstadt, in the countries round Mayence, Oppenheim, and Worms.

It rises to a considerable height at Zeuten and Odenau, east of the Rhine, at a short distance from the Bergstrasse, between Wiesloch and Bruchsal, a locality first pointed out to me by Professor Bronn, where it is several hundred feet thick, and contains, both in the soft loam and in solid calcareous concretions, many shells, some of which retain occasionally their colour. The lower parts of this loess alternate with beds of alluvium derived from the degradation of the variegated sandstone and marl (bunter sandstein), of which the surrounding country is composed.

As the pure loess exhibits no divisions into strata, I at first imagined, with several other geologists, that this deposit was thrown down suddenly from the muddy waters of a transient flood, in the same manner as the moya of the Andes, or as the trass of the Rhine volcanos is generally believed to have been formed. But on re-examining the places where loess and alluvium, or loess and layers of volcanic matter alternate, I am compelled to renounce this view. In the deep gravel pits without the Manheim gate of Heidelberg, loess is seen interstratified with gravel; and here more than one bed containing land and fresh-water shells rests upon, and is covered by, a stratum of gravel, showing the effects of successive accumulation. I observed the same fact in the valley of the Lahn, north of Limburg, near the village of Elz; and Professor Bronn informs me, that the calcareous concretions of the loess are sometimes arranged in horizontal

layers, marking a difference in the carbonate of lime with which the sediment must have been charged at different periods.

Mammiferous remains are rare in the loess; but it is said that the bones of the mammoth, horse, and some other quadrupeds, have been met with: but the most characteristic fossils are land-shells; and it will naturally be asked in what manner so prodigious a quantity of such shells could become buried at various depths in a subaqueous deposit. The answer is, that the Rhine, in our own times, bears down annually to the sea thousands of empty snail-shells, washed away during heavy rains, together with the floating shells of aquatic mollusca from streams, lakes, and stagnant pools. In the summer of 1833, I collected several hundred shells, which were exposed on the margin of the Rhine, on the fall of the waters, or had been cast ashore by large waves raised by the steam-boats; and on comparing them with a still larger collection obtained from the loess, the two groups proved to be referrible for the most part to identical species, and in both the terrestrial predominated numerically over the aquatic species. The genera most abundantly represented in each were Helix, Pupa, Limnea, Paludina, and Planorbis. But among the recent shells of the Rhine, the Unio and Neritina sometimes occurred; genera of which I never found any species in the loess.

Now, it has been ascertained, that the waters of the Rhine, when evaporated, leave a residuum of calcareous loam, not distinguishable from loess*; so that, if

* See Mr. Horner, on the Sediment of the Rhine, Proceedings of Geol. Soc., 1834.

these waters should enter a lake, they might give rise to a deposit, not only containing the same shells as the loess (with the exception of some fluviatile species), but having also the same mineral characters.

The loess is found reposing on every rock, from the granite near Heidelberg, to the gravel of the plains of the Rhine. It overlies almost all the volcanic products, even those between Neuwied and Bonn, which have the most modern aspect; and it has filled up, in part, the crater of the Roderberg; at the bottom of which a well was sunk, in 1833, through seventy feet of loess. Here, as elsewhere, it is a yellow loam with calcareous concretions, and has not the character of a local alluvium.

It is remarkable, indeed, that the loess is scarcely ever affected by the nature of the rocks which underlie or immediately surround its site, but wherever it occurs appears as if derived from one common source.

On revisiting the sections near Andernach, which have been appealed to by MM. Steininger, Hibbert, and others, as proving that some of the last eruptions of the Lower Eifel took place both during and since the deposition of the loess, I found it impossible not to come to the same conclusion. The loamy sediment may be seen in the Kirchweg, above Andernach, alternating with volcanic matter, over which is a mass of pure and unmixed loess, thirty feet and upwards in thickness, containing the usual shells; and over the whole are strewed layers of pumice, lapilli, and volcanic sand, from ten to fifteen feet thick, very much resembling the ejections under which Pompeii lies buried. There is no passage at this upper junction from the loess into the pumiceous superstratum; and

this last follows the slope of the hill, just as it would have done had it fallen in showers from the air on a declivity partly formed of loess.

The greatest known height attained by the loess is near Heilbronn, where it covers the slopes of some hills two or three hundred feet above the Neckar; that river being there about 500 feet above the sea. Whatever theory we adopt to explain the position of such elevated masses, it must always be evident that great geographical changes have taken place in the countries bordering the Rhine since some of the loess was formed, and, consequently, since the recent species of terrestrial and aquatic shells were in existence.

On the other hand, when we find the loess overlying the gravel of the Rhine near Strasburg, Bonn, and other places, we are compelled to admit that a great part of it was formed after the country had acquired nearly its present configuration. The first idea which has probably occurred to every one, after examining the loess between Mayence and Basle, is, to imagine that a great lake once extended throughout the valley of the Rhine between those places, which sent off large branches up the course of the Mayne, Neckar, and other tributary valleys. The barrier of such a lake might be placed somewhere in the narrow and picturesque gorge of the Rhine between Bingen and Bonn. But this theory is insufficient to explain the phenomena; for that gorge itself has once been filled with loess, which must have been tranquilly deposited in it, as also in the lateral valley of the Lahn, communicating with the gorge. The loess has also overspread the high adjoining platform near the village of Plaidt, above Andernach. Nay, on proceeding farther to the north, we discover that the hills which

skirt the valley between Bonn and Cologne have loess on their flanks, which also covers here and there the gravel of the plain as far as Cologne.

Instead of supposing one continuous lake of sufficient extent and depth to allow of the simultaneous accumulation of the loess at various heights, throughout the whole area where it now occurs, it might be a less violent hypothesis to assume that the countries drained by the Rhine and its tributaries, after they had nearly acquired their actual form and leading geographical features, underwent great changes of level, by movements contemporaneous with the last series of volcanic eruptions of the Lower Eifel. Different parts of this region may have been alternately depressed and upraised in such a manner that they were each in their turn submerged beneath the waters of the Rhine, and covered with its sediment and floating shells. Gravel may have been intermingled in some places where the tributaries of the Rhine brought down coarser alluvium. After various tracts had thus been inundated in succession, covered with loess, and then laid dry, the larger portion of the loess must have been removed by denudation ; a process which is still going on continually, as the particles of so fine a loam allow of their being washed away very readily by rain.

It is not, I think, impossible that some of the newly-formed lakes in the basin of Red River, in Louisiana, before described, may have been occasioned by changes in the relative level of the lands there flooded ; for the valley of the Mississippi is one of the modern theatres of earthquakes.* Now, the course of Red River far

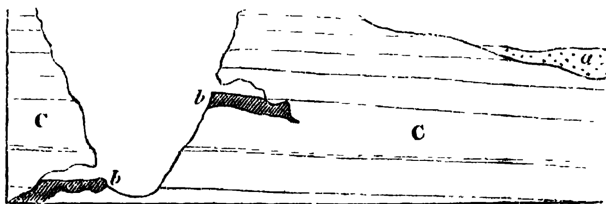
* Vol. I. p. 286.

exceeds in length, and is indeed nearly double, that of the Rhine; and whatever may be the causes which are giving rise to the successive submergence of its plains, they must also occasion the accumulation in many parts of that great valley of the red ochreous sediment so peculiar to Red River.

If the fluctuations in the relative levels of this great American valley should, in the course of ages, be so important as to produce elevations and subsidences to the amount of several hundred feet, the results, in regard to the superficial distribution of red fluviatile mud, might be very analogous to those observed in the position of the yellow loess in the valley of the Rhine above considered.*

Osseous breccias — Sicily. — The breccias lately found in several caves in Sicily belong evidently to the period under consideration. I have shown, in the sixth chapter, that the cavernous limestone of the Val di Noto is of very modern date, as it contains a

Fig. 90.



a. Alluvium, } containing remains of *extinct* quadrupeds.
b, b. Deposits in caves, }
C. Limestone containing remains of *recent* shells.

* For particulars concerning the loess of the Rhine, consult the works of MM. Bronn, Leonhard, Boué, Voltz, Noeggerath, Steininger, Merian, Rozet, Von Meyer, and Hibbert.

great abundance of fossil shells of recent species; and if any breccias are found in the caverns of this rock, they must be of still later origin.

We are informed by M. Hoffmann, that the bones of the mammoth, and of an extinct species of hippopotamus, have been discovered in the stalactite of caves near Sortino, of which the situation is represented in the annexed diagram at *b*. The same author also describes a breccia, containing the bones of an extinct rhinoceros and hippopotamus, in a cave in the neighbourhood of Syracuse, where the country is composed entirely of the Val di Noto limestone. Some of the fragments in the breccia are perforated by lithodomi, and the whole mass is covered by a deposit of marine clay filled with recent shells.* These phenomena may, I think, be explained by supposing such oscillations of level as are known to occur on maritime coasts where earthquakes prevail — such, in fact, as have been witnessed on the shores of the Bay of Baiæ within the last three centuries.† For it is evident that the temporary submergence of a cave filled with osseous breccia might afford time for the perforation of the rock by boring testacea, and for the deposition upon it of mud, sand, and shells.

The association in these and other localities of shells of living species with the remains of extinct mammalia is very distinct, and corroborates the inference adverted to in a former chapter, that the longevity of *species* in the mammalia is, upon the whole, inferior to that of the testacea. I am by no means

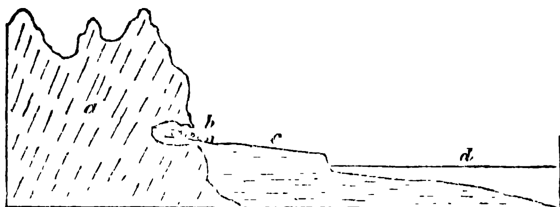
* Hoffmann, Archiv für Mineralogie, p. 393. Berlin, 1831. Dr. Christie, Proceedings of Geol. Soc., No. xxiii. p. 333.

† Vol. II. p. 312.

inclined to refer this circumstance to the intervention of man, and his power of extirpating the larger quadrupeds; for the succession of mammiferous species appears to have been in like manner comparatively rapid throughout the older tertiary periods. Their more limited duration depends, in all probability, on physiological laws, which render warm-blooded quadrupeds less capable, in general, of accommodating themselves to a great variety of circumstances, and, consequently, of surviving the vicissitudes to which the earth's surface is exposed in a great lapse of ages.*

Caves near Palermo. — The caves near Palermo exhibit appearances very analogous to those above described, and much curious information has been

Fig. 91.



a. Monte Grifone. b. Cave of San Ciro.
c. Plain of Palermo, in which are Newer Pliocene strata of limestone and sand.
d. Bay of Palermo. †

* See Vol. III. p. 121., and book i. chap. vi.

† This section is given by the late Dr. Christie, as of the Cave of San Ciro. Ed. New Phil. Journ., No. xxiii. It was called by mistake the Cave of Mardolce, by M. Hoffmann. An account has since appeared by Mr. S. P. Pratt, F.G.S.: see the Proceedings of Geol. Soc. of London, No. 32. 1833.

lately published respecting them. According to Hoffmann, the grotto of San Ciro is distant about two miles from Palermo, and is twenty feet high and ten wide. It occurs in a secondary limestone, in the Monte Grifone, at the base of a rocky precipice about 180 feet above the sea. From the foot of this precipice an inclined plane, consisting of horizontal tertiary strata, of the Newer Pliocene period, extends to the sea, a distance of about a mile.

The limestone escarpment was evidently once a sea-cliff, and the ancient beach still remains formed of pebbles of various rocks, many of which must have been brought from places far remote. Broken pieces of coral and shell, especially of oysters and pectens, are seen intermingled with the pebbles. Immediately above the level of this beach, serpulæ are still found adhering to the face of the rock, and the limestone is perforated by lithodomi. Within the grotto, also, at the same level, similar perforations occur; and so numerous are the holes, that the rock is compared by Hoffmann to a target pierced by musket balls. But in order to expose to view these marks of boring-shells in the interior of the cave, it was necessary first to remove a mass of breccia, which consisted of numerous fragments of rock and an immense quantity of bones imbedded in a dark brown calcareous marl. Many of the bones were rolled as if partially subjected to the action of the waves. Below this breccia, which is about twenty feet thick, was found a bed of sand filled with sea-shells of recent species; and underneath the sand, again, is the secondary limestone of Monte Grifone. The state of the surface of the limestone in the cave above the level of the marine sand is very different from that below it. *Above*, the rock is jagged and

uneven, as is usual in the roofs and sides of limestone caverns; *below*, the surface is smooth and polished, as if by the attrition of the waves.

So enormous was the quantity of bones, that many ship-loads were exported in the years 1829 and 1830, in the hope of their retaining a sufficient quantity of gelatine to serve for refining sugar; for which, however, they proved useless. The bones belong chiefly to the mammoth (*E. primigenius*), and with them are those of an hippopotamus, distinct from the recent species, and smaller than that usually found fossil. Several species of deer, also, and, according to some accounts, the remains of a bear, were discovered.

It is easy to explain in what manner the cavern of San Ciro was in part filled with sea-sand, and how the surface of the limestone became perforated by lithodomi; but in what manner, when the elevation of the rocks and the ancient beach had taken place, was the superimposed osseous breccia formed? For want of more exact local details, it would be rash to speculate on this subject; but by referring to what was previously said of cavrens near the sea-shore of the Morea, from which rivers escape, the reader may conceive that caves, after having been submerged and filled with sea-sand, may afterwards be upraised and flooded by the waters of engulphed rivers washing down animal remains from the land.*

Two other caverns are described by Dr. Christie as occurring in Mount Beliemi, about four miles west of Palermo, at a higher elevation than that of San Ciro, being more than three hundred feet above the level of

* See Vol. III. p. 228.

the sea. In one of these places the bones are found only in a talus at the outside of the cavern; in the other, they occur both within the cave and in the talus which slopes from it to the plain below. These caves appear to be situated much above the highest point attained by the tertiary deposits in this neighbourhood; nor is there the slightest appearance in the caves themselves of the sea having been there.*

Australian cave-breccias. — Ossiferous breccias have lately been discovered in fissured and cavernous limestone in Australia, and the remains of the fossil mammalia are found to be referrible to species now living in that country, mingled with some relics of extinct animals. Some of these caves have been examined by Major Mitchell, in the Wellington Valley, about 210 miles west of Sydney, on the river Bell, one of the principal sources of the Macquarie, and on the Macquarie itself.

The fissures and caverns appear to correspond closely with those which contain similar osseous breccias in Europe: they often branch off in different directions through the rock, widening and contracting their dimensions, the roofs and floors being covered with stalactite. The bones are often broken, but do not seem to be water-worn. In some caves and fissures they lie imbedded in loose earth, but usually they are included in a breccia, having a red ochreous cement as hard as limestone, and like that of the Mediterranean caves.

The remains found most abundantly are those of the kangaroo. Amongst others, those of the Wombat

* Dr. T. Christie, on certain Newer Deposits in Sicily, &c. — Jameson, Ed. New Phil. Jour., No. xxiii. p. 1.

Dasyurus, Kaola, and Phalangista, have been recognized. The greater part of them belong to existing, but some to extinct, species. One of the latter bones, of much greater size than the rest, is supposed, by Mr. Clift, to belong to an hippopotamus.*

In a collection of these bones sent to Paris, Mr. Pentland thought he could recognize a species of Halmaturus exceeding in size the largest living kangaroo.†

These facts are full of interest, for they prove that the peculiar type of organization which now characterizes the marsupial tribes has prevailed from a remote period in Australia; and that in that continent, as in Europe, North and South America, and India, some species of mammalia have become extinct. It also appears, although the evidence on this point is still incomplete, that among the extinct were land quadrupeds far exceeding in magnitude any of the wild animals now inhabiting New Holland.‡

Newer Pliocene Alluviums. — Some writers have attempted to introduce into their classification of geological periods an *alluvial epoch*, as if the transportation of loose matter from one part of the surface of the land to another had been the work of one particular period.

With equal propriety might they have endeavoured to institute a volcanic period, or a period of marine

* Mr. Clift, Ed. New Phil. Journ., No. xx. p. 394. Major Mitchell, Proceedings of Geol. Soc., 1831, p. 321.

† Journ. de Géologie, tome iii. p. 291. The bone mentioned as that of an *elephant* by Mr. Pentland, was the same large bone alluded to by Mr. Clift.

‡ For remarks on the mode in which these caverns may have been filled with osseous breccias, see Vol. III. p. 225.

or freshwater deposition; for alluvial formations must have originated in every age, since the surface of the earth was first divided into land and sea, but most rapidly in any given district at those periods when land has been upheaved above, or depressed below, its former level.*

If those geologists who speak of an "alluvial epoch" intend merely to say that a great part of the European alluviums are *tertiary*, there may undoubtedly be some truth in the opinion; for the larger part of the existing continent of Europe has emerged from beneath the waters during some one or other of the tertiary periods †; and it is probable, that even those districts which were land before the commencement of the tertiary epoch, may have shared in the subterranean convulsions by which the levels of adjoining countries have since been altered. During such subterranean movements new alluviums might be formed in great abundance, and those of more ancient date so modified as to retain scarcely any of their original distinguishing characters.

During the gradual rise of a large area, first from beneath the waters, and then to a great height above them, several kinds of superficial gravel must be formed and transported from one place to another. When the first islets begin to appear, and the breakers are foaming upon the new-raised reefs, many rocky fragments are torn off and rolled along the bottom of the sea.

Let the reader recall to mind the action of the tides and currents off the coast of Shetland, where blocks of granite, gneiss, porphyry, and serpentine, of enor-

* See definition of alluvium, Vol. III. p. 218.

† See map, Vol. I. p. 209.

mous dimensions, are continually detached from wasting cliffs during storms, and carried in a few hours to a distance of many hundred yards from the parent rocks.* Suppose the floor of the ocean, after being thus strewed over with detached blocks and pebbles, to be converted partially into land, the geologist might then, perhaps, search in vain for the masses from which the fragments were originally derived, since part of these may have been consumed by the waves, and the rest may remain submerged beneath them.

If this new land be then uplifted to a considerable height, the marine alluvium before alluded to would be raised up on the summits of the hills and on the surface of elevated platforms. It might still constitute the general covering of the country, being wanting only in such valleys and ravines as may have been caused by earthquakes, or excavated by the power of running water during the rise of the land; for the alluvium in those more modern valleys would consist partly of pebbles washed out of the older gravel before mentioned, but chiefly of fragments derived from the rocks which were removed during the erosion of the valleys themselves.

Erratic blocks.—Blocks of extraordinary magnitude have been observed at the foot of the Alps, and at a considerable height in some of the valleys of the Jura, exactly opposite the principal openings by which great rivers descend from the Alps. These fragments have been called "erratic," and many imaginary causes have been invented to account for their transportation. Some have talked of chasms opening in the ground immediately below, and of huge fragments

* See Vol. II . p. 12.

having been cast out of them from the bowels of the earth. Others have referred to the deluge, an agent in which a simple solution is so often found of every difficult problem exhibited by alluvial phenomena; and more recently, the sudden rise of mountain-chains has been introduced as a cause which may have given rise to diluvial waves, capable of devastating whole continents, and drifting huge blocks from one part of the earth's surface to another.

It seems necessary to suppose that the Jura once formed a prolongation of the Alps, and that large fragments of rock were, at a remote period, detached from the Alpine summits, and transported to lower hills or platforms, which were destined afterwards to be upraised and to form the independent chain now called the Jura. Ice, as has been often suggested, may have contributed its aid to the transfer of such blocks; for some of the masses are so enormous, that not even a flood like that in the valley of Bagnes, in 1818*, can be supposed to have conveyed them to considerable distances by the power of water alone.

That the Alps must have been moved and shaken by earthquakes at periods comparatively modern, is evident from the fact that they are skirted on their northern, southern, and eastern flanks by marine tertiary strata. When these were raised into their present position, to the height of many hundred feet above the sea, the whole of the older chain must have participated in the convulsions.

It is important, therefore, to consider what would now happen if regions like that of Mont Blanc were subjected to earthquakes. Large fragments of rock,

* See Vol. I. p. 291.

detached by the action of rain and frost from the peaks "or needles," as they are called, of Chamouni, fall annually on the surface of the glaciers, and are gradually transported by ice to the distance of many leagues into the valleys below.* The shock of an earthquake would throw down a prodigious load of similar but far heavier masses, accompanied by avalanches of snow and ice, by which the moraine of the glacier would be greatly enlarged. If the shocks took place on the eve of a thaw in spring, when the accumulated snows of winter were beginning to melt, they would cause almost every where immense avalanches, by which many narrow gorges might be choked up, so that the valleys above such barriers of snow, ice, and rock would be converted into lakes. Portions of the rent glaciers, moreover, would at their lower extremities be covered with water, and might be floated off together with incumbent and included fragments of rock. At length, on the bursting of the temporary barrier, the whole mass of waters, together with huge rocks buoyed up by ice, would descend with tremendous violence into the lower country.

The manner in which the ice of rivers and of the sea itself contributes, in the Baltic and other northern regions, to transport large blocks, as well as smaller pieces of stone, to vast distances, has been treated of in a former chapter.†

Sicily.—Assuming, then, that almost all the European alluviums are tertiary, we have next to inquire which of them are of Newer Pliocene origin. It is clear that, when a district, like the Val di Noto, is composed of rocks of this age, all the alluvium upon

* Vol. I. p. 265. † See Vol. I. p. 267.

the surface must necessarily belong either to the Newer Pliocene or the Recent epoch. If, therefore, the elevation of the mountains of the Val di Noto was chiefly accomplished antecedently to the Recent epoch, we must at once pronounce all alluviums, in the position indicated at *a*, Fig. 90. (p. 51.), to belong to the Newer Pliocene era. I saw gravel so situated at Grammichele in Sicily, and was informed that it contained the bones of the mammoth.

Sweden.—I also believe that a large portion of what is usually termed diluvium, spread over the land bordering the eastern and western coasts of Sweden, may properly be called alluvium of the Recent and Newer Pliocene periods.

CHAPTER XII.

OLDER PLIOCENE FORMATIONS.

Geological monuments of the *older* Pliocene period — Subapennine formations — Opinions of Brocchi — Different groups termed by him Subapennine are not all of the same age — Mineral composition of the Subapennine formations — Marls — Yellow sand and gravel — Subapennine beds, how formed (p. 70.) — Illustration derived fromt he Upper Val d'Arno — Organic remains of Subapennine hills — Older Pliocene strata at the base of the Maritime Alps — Genoa (p. 77.) — Savona — Albenga — Nice — Conglomerate of Valley of Magnan — Its origin — Tertiary strata at the eastern extremity of the Pyrenees.

Subapennine strata. — We must now carry our retrospect one step farther, and treat of the monuments of the era immediately antecedent to that last considered. The Apennines, it is well known, are composed chiefly of secondary rocks, forming a chain which branches off from the Ligurian Alps and passes down the middle of the Italian peninsula. At the foot of these mountains, on the side both of the Adriatic and the Mediterranean, are found a series of tertiary strata, which form, for the most part, a line of low hills occupying the space between the older chain and the sea. Brocchi, the first Italian geologist who described this newer group in detail, gave it the name of the Subapennines; and he classed all the tertiary strata of Italy from Piedmont to Calabria, as parts of the same system. Certain mineral characters, he observed, were

common to the whole; for the strata consist generally of light brown or blue marl, covered by yellow calcareous sand and gravel. There are also, he added, some species of fossil shells which are found in these deposits throughout the whole of Italy.

In a catalogue, published by Lamarck, of five hundred species of fossil-shells of the Paris basin, a small number only were enumerated as identical with those of Italy, and only twenty as agreeing with living species. This result, said Brocchi, is wonderful, and very different from that derived from a comparison of the fossil-shells of Italy, *more than half of which* agree with species now living in the Mediterranean, or in other seas chiefly of hotter climates.*

He also stated, that it appeared from the observations of Parkinson, that the clay of London, like that of the Subapennine hills, was covered by sand (alluding to the crag), and that in that upper formation of sand in England the species of shells corresponded much more closely with those now living in the ocean than did the species of the subjacent clay. Hence he inferred that an interval of time had separated the origin of the two groups. But in Italy, he goes on to say, the shells found in the marl and superincumbent sand belong entirely to the same group, and must have been deposited under the same circumstances.†

Notwithstanding the correctness of these views, Brocchi conceived that the Italian tertiary strata, as a whole, might agree with those of the basins of Paris and London; and he endeavoured to explain the discordance of their fossil contents by remarking, that the

* Conch. Foss. Subap., tom. i. p. 148.

† Ibid., p. 147.

testacea of the Mediterranean differ now from those living in the ocean.* In attempting thus to assimilate the age of these distinct groups, he was evidently influenced by his adherence to the anciently received theory of the gradual fall of the level of the ocean, to which, and not to the successive rise of the land, he attributed the emergence of the tertiary strata; all of which he consequently imagined to have remained under water down to a comparatively recent period.

Brocchi was perfectly justified in affirming that there were some species of shells common to all the strata called by him Subapennine; but I have shown that this fact is not inconsistent with the conclusion, that the several deposits may have originated at different periods, for there are species of shells common to all the tertiary eras. He seems to have been aware, however, of the insufficiency of his data; for in giving a list of species universally distributed throughout Italy, he candidly admits his inability to determine whether the shells of Piedmont were all identical with those of Tuscany, and whether those of the northern and southern extremities of Italy corresponded.†

We have already satisfactory evidence that the Subapennine beds of Brocchi belonged, at least, to three periods. To the Miocene we can refer a portion of the strata of Piedmont, those of the hill of the Superga, for example; to the Older Pliocene belong the greater part of the strata of northern Italy and of Tuscany, and perhaps those of Rome; to the Newer Pliocene, the tufaceous formations of Naples, the calcareous strata of Otranto, and probably the greater part of the tertiary beds of Calabria.

* Conch. Foss. Subap., tom. i. p. 166. † Ibid., p. 143.

That there is a considerable correspondence in the arrangement and mineral composition of these different Italian groups, is undeniable; but not that close resemblance which should lead us to assume an exact identity of age, even had the fossil remains been less dissimilar.

Very erroneous notions have been entertained respecting the contrast between the lithological characters of the Italian strata and certain groups of higher antiquity. Dr. Macculloch has treated of the Italian tertiary beds under the general title of "elevated submarine alluvia;" and the overlying yellow sand and gravel may, according to him, be wholly, or in part, a terrestrial alluvium.* Had he visited Italy, I am persuaded that he would never have considered the tertiary strata of London and Paris as belonging to formations of a different order from the Subapennine groups, or as being more regularly stratified. He seems to have been misled by Brocchi's description, who contrasts the more crystalline and solid texture of the older secondary rocks of the Apennines with the loose and incoherent nature of the Subapennine beds, which resemble, he says, the mud and sand now deposited by the sea.

I have endeavoured, in a former chapter, to restrict within definite limits the meaning of the term *alluvium* † ; but if the Subapennine beds are to be designated "marine alluvia," the same name might, with equal propriety, be applied not only to the argillaceous and sandy groups of the London and Hampshire basins, but to a very great portion of our se-

* Syst. of Geol., vol. i. chap. xv.

† Vol. III. p. 218.

condary series where the marls, clays, and sands are as imperfectly consolidated as are the tertiary strata of Italy in general.

They who have been inclined to associate the idea of the more stony texture of stratified deposits with a comparatively higher antiquity, should consider how dissimilar, in this respect, are the tertiary groups of London and Paris, although admitted to be of contemporaneous date; or they should visit Sicily, and behold a soft brown marl, identical in mineral character with that of the Subapennine beds, underlying a mass of solid and regularly stratified limestone, rivalling the chalk of England in thickness. This Sicilian marl is older than the superincumbent limestone, but newer than the Subapennine marl of the north of Italy; for in the latter the extinct shells rather predominate over the recent; in the Sicilian strata the recent species predominate almost to the exclusion of the extinct.

Subapennine marls. — I shall now consider more particularly the characters of those Subapennine beds which may be referred to the Older Pliocene period.

The most important member of the Subapennine formation is a marl which varies in colour from greyish brown to blue. It is very aluminous, and usually contains much calcareous matter and scales of mica. It often exhibits no lines of division throughout a considerable thickness, but in other places it is thinly laminated. Near Parma, for example, I have counted thirty distinct laminæ in the thickness of an inch. In some of the hills near that city the marl attains, according to Signor Guidotti, a thickness of nearly two thousand feet, and is charged throughout with shells, many of which are such as inhabit a deep sea. They often occur in layers in such a manner as to

indicate their slow and gradual accumulation. They are not flattened, but are filled with marl. Beds of lignite are sometimes interstratified, as at Medesano, four leagues from Parma; subordinate beds of gypsum also occur in many places, as at Vigolano and Bargone, in the territory of Parma, where they are interstratified with shelly marl and sand. At Lezignano, in the Monte Cerio, the sulphate of lime is found in lenticular crystals, in which unaltered shells are sometimes included. Signor Guidotti, who showed me specimens of this gypsum, remarked, that the sulphuric acid must have been fully saturated with lime when the shells were enveloped, so that it could not act upon the shell. According to Brocchi, the marl sometimes passes from a soft and pulverulent substance into a compact limestone, but it is rarely found in this solid form.* It is also occasionally interstratified with sandstone.

The marl constitutes very frequently the surface of the country, having no covering of sand. It is sometimes seen reposing immediately on the Apennine limestone; more rarely gravel intervenes, as in the hills of San Quirico.† Volcanic rocks are here and there superimposed, as at Radicofani, in Tuscany, where a hill composed of marl, with some few shells interspersed, is capped by basalt. Several of the volcanic tuffs in the same place are so interstratified with the marls as to show that the eruptions took place in the sea during the Older Pliocene period. At Acquapendente, Viterbo, and other places, hills of the same formation are capped with trachytic lava, and

* Conch. Foss. Subap., tom. i. p. 82. † Ibid., p. 78.

with tuffs which appear evidently to have been subaqueous.

Yellow sand. — The other member of the Subapennine group, the yellow sand and conglomerate, constitutes, in most of the places where I have seen it, a border formation near the junction of the tertiary and secondary rocks. In some cases, as near the town of Sienna, we see sand and calcareous gravel resting immediately on the Apennine limestone, without the intervention of any blue marl. Alternations are there seen of beds containing fluviatile shells, with others filled exclusively with marine species; and I observed oysters attached to many of the pebbles of limestone. This appears to have been a point where a river, flowing from the Apennines, entered the sea in which the tertiary strata were formed.

Between Florence and Poggibonsi, in Tuscany, there is a great range of conglomerate of the Subapennine beds, which is seen for eleven miles continuously from Casciano to the south of Barberino. The pebbles are chiefly of whitish limestone, with some sandstone. On receding from the older Apennine rocks, the conglomerate passes into yellow sand and sandstone, with shells, the whole overlying blue marl. In such cases we may suppose the deltas of rivers and torrents to have gained upon the bed of a sea where blue marl had previously been deposited.

The upper arenaceous group above described sometimes passes into a calcareous sandstone, as at San Vignone. It contains lapidified shells more frequently than the marl, owing probably to the more free percolation of mineral waters, which often dissolve and carry away the original component elements of fossil bodies and substitute others in their place. In some

cases the shells imbedded in this group are silicified, as at San Vitale, near Parma, from whence I saw two individuals of recent species, one fresh-water and the other marine (Limnea palustris, and Cytherea concentrica, Lamk.), both perfectly converted into flint.

On the other hand, the shells of Monte Mario, near Rome, which are probably referrible to the same formation, are changed into calcareous spar, the form being preserved notwithstanding the crystallization of the carbonate of lime.

Mode of formation of the Subapennine beds. — The tertiary strata above described have resulted from the waste of the secondary rocks which now form the Apennines, and which had become dry land before the Older Pliocene beds were deposited. In the territory of Placentia we have an opportunity of observing the kind of sediment which the rivers are now bringing down from the Apennines. The tertiary marl of that district being too calcareous to be used for bricks or pottery, a substitute is obtained by conveying into tanks the turbid waters of the rivers Braganza, Parma, Taro, and Enza. In the course of a year a deposit of brown clay, much resembling some of the Subapennine marl, is procured, several feet in thickness, divided into thin laminæ of different shades of colour.

In regard to the sand and gravel, we see yellow sand thrown down by the Tiber near Rome, and by the Arno, at Florence. The northern part of the Apennines consists of a grey micaceous sandstone with an argillaceous base, alternating with shale, from the degradation of which brown clay and sand would result. If a river flow through such strata, and some one of its tributaries drains the ordinary limestone of the Apennines, the clay might become marly by the

intermixture of calcareous matter. The sand is frequently yellow from being stained by oxide of iron; but this colour is by no means constant.

The similarity in composition of the tertiary strata in the basins of the Po, the Arno, and the Tiber, is merely such as might be expected to arise from their having been all derived from the disintegration of the same continuous chain of secondary rocks. But it does not follow that the latter rocks were all upheaved and exposed to degradation at the same time. The correspondence of the tertiary groups consists in their being all alike composed of marl, clay, and sand; but we might say as much of the beds of the London and Hampshire basins, although the English and Italian groups, thus compared, belong nearly to the two opposite extremes of the tertiary series.

The similarity in mineral character of the lacustrine deposit of the Upper Val d'Arno, and the marine Subapennine hills of northern Italy, ought to serve as a caution to the geologist, not to infer too hastily a contemporaneous origin from identity of mineral composition. The deposit of the Upper Val d'Arno occurs nearly at the bottom of a deep narrow valley, which is surrounded by precipitous rocks of secondary sandstone and shale (the macigno of the Italians, and greywacké of the Germans). Hills of yellow sand, of considerable thickness, appear around the margin of the small basin; while, towards the central parts, where there has been considerable denudation, and where the Arno flows, blue clay is seen underlying the yellow sand. The shells are of fresh-water origin, but I shall speak more particularly of them when discussing the probable age of this formation in the sixteenth chapter. I desire at present to call attention

to the fact, that we have here, in an isolated basin, such a formation as would result from the waste of the contiguous secondary rocks of the Apennines, fragments of which rocks are found in the sand and conglomerate. We might expect that, if the fresh-water beds were removed, and the barrier of the lake-basin closed up again, similar sediment would be again deposited; since the aqueous agents would operate in the same manner, at whatever period they might be in activity. Now, the only difference in mineral composition, between the lacustrine deposit and the ordinary marine Subapennine strata, consists in the absence of calcareous matter from the clay; and this may be ascribed to the circumstance that the torrents flowing into the lake had passed over no limestone rocks.

The lithological character of the Subapennine beds varies in different parts of the Peninsula both in colour and degree of solidity. The presence, also, or absence of lignite and gypsum, and the association or non-association of volcanic rocks, are causes of great local discrepancy. The superposition of the sand and conglomerate to the marl, on the other hand, is a general point of agreement, although there are exceptions to the rule, as at San Quirico before mentioned. The cause of this arrangement may be, as I before hinted, that the arenaceous groups were first formed on the coast where rivers entered; and when these pushed their deltas farther out, they threw down the sand upon part of the bed of the sea already occupied by finer and more transportable mud.

Captain Bayfield, in his Survey of the Coast of St. Lawrence, mentions horizontal strata of sand and gravel, and a subjacent deposit of clay as reposing in depressions in the older rocks near the shore. The

clay invariably occupies the lowest position, and the gravel the highest; and this arrangement, he says, may be explained by considering that the rivers where they now bring down alluvial matter on several parts of this coast, carry gravel over a bottom previously occupied by clay, the finer sediment having first been drifted farther from the shore.*

When Captain Bayfield proposed this theory, he had not seen my work just then published†; it was satisfactory therefore to observe the exact coincidence of his views with my own, his having been suggested by the modern changes going on in the St. Lawrence, mine by reasoning on appearances in the interior of Italy.

Organic remains. — Figures of some of the most abundant shells of the Subapennine formations are given in the accompanying plate. (Pl. X.) The greater part of them are common both to the Older and Newer Pliocene periods of this work. Eight of the species, Nos. 1, 3, 5, 6, 7, 9, 13, and 14, are now living, but are also common in the *older* Pliocene formations. Fusus crispus has not been found either *recent*, or in the Miocene or Eocene formations, but occurs both in the Older and Newer Pliocene formations. Mitra plicatula has been observed only in the Older Pliocene deposits. The Turbo rugosus was formerly considered as exclusively Pliocene; but M. Boué has since found it in the Miocene strata at Vienna and Moravia. Buccinum semistriatum is also a Miocene shell, but has been inserted as being peculiarly abundant in the Pliocene strata.

The Subapennine testacea are referrible to species

* An abstract of this paper will be found in the Proceedings of the Geol Soc., No. 33. p. 4.

† First edition of 3d Vol. p. 162.

and families of which the habits are extremely diversified, some living in deep, others in shallow water, some in rivers or at their mouths. I have seen a specimen of a *fresh-water* univalve (*Limnea palustris*), taken from the blue marl near Parma, full of small *marine* shells. It may have been floated down by the same causes which carried wood and leaves into the ancient sea.

I have been informed, by experienced collectors of the Subapennine fossils, that they invariably procure the greatest number in those winters when the rains are most abundant; an annual crop, as it were, being washed out of the soil to replace those which the action of moisture, frost, and the rays of the sun soon reduce to dust upon the surface.

The shells, in general, are soft when first taken from the marl, but they become hard when dried. The superficial enamel is often well preserved, and many shells retain their pearly lustre, and part of their external colour, and even the ligament which unites the valves. No shells are more usually perfect than the microscopic, which abound near Sienna, where more than a thousand full-grown individuals are sometimes poured out of the interior of a single univalve of moderate dimensions. In some large tracts of yellow sand it is impossible to detect a single fossil, while in other places they occur in profusion.

Blocks of Apennine limestone are found in this formation drilled by lithodomous shells. The remains not only of testacea and corals, but of fishes and crabs, are met with, as also those of cetacea, and even of terrestrial quadrupeds.

A considerable list of the mammiferous species has been given by Brocchi and some other writers; and,

although several mistakes have been made, and some bones of cetacea have been confounded with those of land animals, it is still indubitable that some remains of land animals were carried down into the sea when the Subapennine sand and marl were accumulated. The same causes which drifted skeletons into lakes, such as that of the Upper Val d'Arno, may have carried down others into firths or bays of the sea. The femur of an elephant has been disinterred with oysters attached to it, showing that it remained for some time exposed after it was drifted into the sea.

Strata at the base of the Maritime Alps. — If we pass from the Italian peninsula, and, following the borders of the Mediterranean, examine the tertiary strata at the foot of the Maritime Alps, we find formations agreeing in zoological characters with the Subapennine beds, and presenting many points of analogy in their mineral composition. The Alps, it is well known, terminate abruptly in the sea, between Genoa and Nice, and the steep declivities of that bold coast are continued below the waters; so that a depth of many hundred fathoms is often found within stone's-throw of the beach. Exceptions occur only where streams and torrents enter the sea; and at these points there is always a low level tract, intervening between the mouth of the stream and the precipitous escarpment of the mountains.

In travelling from France to Genoa, by the new coast road, we are conveyed principally along a ledge excavated out of a steep slope or precipice, in the same manner as on the roads which traverse the great interior passes of the Alps, such as the Simplon and Mont Cenis; the difference being that, in this case, the traveller has always the sea below him, instead of a

river. But we are obliged occasionally to descend by a zigzag course into those low plains before alluded to, which, when viewed from above, have the appearance of bays deserted by the sea. They are surrounded on three sides by rocky eminences, and the fourth is open to the sea.

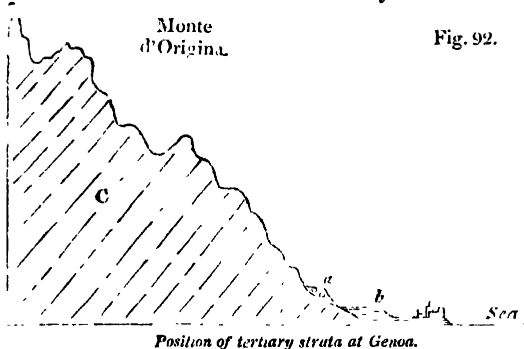
These leading features in the physical geography of the country are intimately connected with its geological structure. The rocks composing the Alpine declivities belong partly to the primary formations, but more generally to the secondary, and have undergone immense disturbance; but when we examine the low tracts before mentioned, we find the surface covered with great beds of gravel and sand, such as are now annually brought down by torrents and streams in the winter, and which are spread in such quantity over the wide and shifting river-channels as to render the roads for a season impassable. The first idea which naturally suggests itself, on viewing these plains, is to imagine them to be deltas or spaces converted into land by the accumulated sand and gravel brought down from the Alps by rivers. But, on closer inspection, we find that the apparent lowness of the plains, which at first glance might be supposed to be only just raised above the level of the sea, is a deception produced by contrast. The Alps rise suddenly to the height of several thousand feet with a bold and precipitous outline; while the country below is composed of horizontal strata, which have either a flat or gently undulating surface. These strata consist of gravel, sand, and marl, filled with marine shells, and they are considerably elevated, attaining sometimes the height of two hundred feet, or even more, above the level of the sea; there must, therefore, have been a rise of the coast since they were deposited, and they are not mere deltas or spaces re-

claimed from the sea by rivers. Why, then, are such strata found only at the points where rivers enter?

We must imagine that, after the coast had nearly acquired its present configuration, the streams which flowed down into the Mediterranean produced shoals opposite their mouths by the continual drifting in of gravel, sand, and mud. The Alps have since been raised to a sufficient height to cause these shoals to become land; while the corresponding elevation of the intervening parts of the coast, where the sea was of great depth near the shore, has not been perceptible.

The disturbing force appears to have acted very irregularly, and to have produced the least elevation towards the eastern extremity of the Maritime Alps, and a greater amount as we proceed westward. Thus we find the marine tertiary strata attaining the height of about 100 feet at Genoa, 200 and 300 feet farther westward at Albenga, and 800 or 900 feet in the neighbourhood of Nice.

Genoa. — At Genoa the tertiary strata consist of



Position of tertiary strata at Genoa.

a. Ancient sea-beach. *b*. Blue marl with shells.
C. Inclined secondary strata of sandstone, shale, &c.

blue marls like those of the northern Subapennines and contain the same shells. On the immediate site of the town they rise to the height of only twenty feet above the sea; but they reach about eighty feet in some parts of the suburbs. At the base of a mountain not far from the suburbs there is an ancient beach, strewed with rounded blocks of Alpine rocks, some of which are drilled by the *Modiola lithophaga*, Lamk., the whole cemented into a conglomerate, which marks the ancient sea-beach at the height of 100 feet above the present sea.*

Savona. — At Savona, proceeding westwards, we find deposits of blue marl like those of Genoa, and occupying a corresponding geological position at the base of the mountains near the sea. The shells, collected from these marls by Mr. Murchison and myself, in 1828, were examined by Signor Bonelli, of Turin, and found to agree with Subapennine fossils.

Albenga. — At Albenga these formations occupy a more extensive tract, forming the plains around that town and the low hills of the neighbourhood, which reach in some spots an elevation of 300 feet. The encircling mountains recalled to my mind those which bound the plain and bay of Palermo, and other bays of the Mediterranean, which are surrounded by bold rocky coasts.

The general resemblance of the Albenga strata to the Subapennine beds is very striking; the lowest division consisting of blue marl which is covered by sand and yellow clay, and the highest by a mass of stratified shingle, sometimes consolidated into a con-

* I have here to acknowledge my obligations to Professor Viviani, and Dr. Sasso, who called my attention to these phenomena when I visited Genoa in Jan. 1829.

glomerate. Dr. Sasso has collected about 200 species of shells from these beds; and it appears, by his catalogue, that they agree, for the most part, with the northern Subapennine fossils, more than half of them belonging to recent species.*

Nice. — At Nice the tertiary strata are upraised to a much greater height, but they may still be said to lie at the base of the Alps which tower above them. Here, also, they consist principally of blue marl and yellow sand, which appear to have been deposited in submarine valleys previously existing in the inclined secondary strata. In one district, a few miles to the west of Nice, the tertiary beds are almost exclusively composed of conglomerate, from the point of their junction with the secondary strata to the sea.

The river Magnan flows in a deep valley, which terminates at its upper extremity in a narrow ravine. Nearly vertical precipices are laid open on each side, varying from 200 to 600 feet in height, and composed of inclined beds of shingle, sometimes separated by layers of sand, and more rarely by blue micaceous marl. The pebbles in these stratified shingles agree in composition with those now brought down from the Alps by the Var and other rivers on this coast.

The dip of these strata is remarkably uniform, being always southwards, or towards the Mediterranean, at an angle of about 25°. I examined this section in company with Mr. Murchison in the summer of 1828, when the bed of the river was dried up. The geologist has then a good opportunity of examining a section of the strata, as the channel crosses for many miles the line of bearing of the beds, which may be

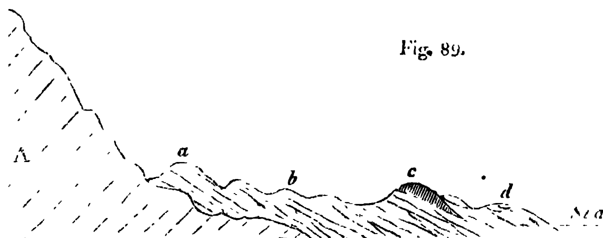
* Giornale Ligustico, Genoa, 1827.

traced to the base of Monte Calvo, a distance of about nine miles in a straight line from the Mediterranean. It is usually impossible to determine the exact age of such accumulations of sand and gravel, in consequence of the total absence of organic remains. Their non-existence may depend chiefly on the disturbed state of the waters, where great beds of shingle are formed, which are known to prevent testacea and fishes from living in Alpine torrents; partly on the total destruction of shells by the same friction which rounded the pebbles; and partly on the permeability of the matrix to water, which may carry away the elements of the decomposing fossil body, without substituting any other substance in their place which might retain a cast of their form.

But it fortunately happens, in this instance, that in some few seams of loamy marl, intervening between the pebble-beds, and near the middle of the section, shells have been preserved in a very perfect state; and these may furnish a zoological date to the whole mass. The principal of these interstratified masses of loam occurs near the church of St. Madeleine (at *c*, diagram No. 93.), where the active researches of M. Risso have brought to light a great number of shells which agree perfectly with the species found in much greater abundance at a spot called La Trinità, and some other places nearer Nice. From these fossils it clearly appears that the formation belongs to the Older Pliocene era.

Such alternations of gravel with the usual thin layers of fine sediment may easily be explained, if we reflect that the rivers now flowing from the Maritime Alps are nearly dried up in summer, and have only strength to drift along fine mud to the sea; whereas

in winter, or on the melting of the snow, they roll along large quantities of pebbles. The thicker masses of loam, such as that of St. Madeleine, may have been produced during a longer interval, when the river shifted for a time the direction of its principal channel of discharge; so that nothing but fine mud was for a series of years conveyed to that point in the bed of the sea opposite the delta.



Section from Monte Calvo to the sea by the valley of Magnan, near Nice

A. Dolomite and sandstone. (Green-sand formation ?)
a, *b*, *d*. Beds of gravel and sand.
c. Fine marl and sand of St. Madeleine.

Uniform and continuous as the strata appear, on a general view, in the ravine of the Magnan, we discover, if we attempt to trace any one of them for some distance, that they thin out and are wedge-shaped. We believe that they were thrown down originally upon a steep slanting bank or talus, which advanced gradually from the base of Monte Calvo to the sea. The distance between these points is, as before mentioned, about nine miles; so that the accumulation of superimposed strata would be a great many miles in thickness, if they were placed horizontally upon one another.

The strata nearest to Monte Calvo, which may be expressed by *a*, are certainly older than those at *b*, and the group *b* was formed before *c*. The aggregate thickness, in any one place, cannot be proved to amount to 1000 feet, although it may, perhaps, be much greater. But it may never exceed 3000 or 4000 feet; whereas, if we did not suppose that the beds were originally deposited in an inclined position, we should be forced to imagine that a sea, many miles in depth, had been filled up by horizontal strata of pebbles thrown down one upon another.

At no great distance on this coast the Var is annually seen to sweep down into the sea a large quantity of gravel, which may be spread out by the waves and currents over a considerable space. The sea at the mouth of this river is now shallow, but it may originally have been 3000 feet deep, as it is now close to the shore at Nice. Here, therefore, a formation resembling that of the Magnan above described may be in progress.

In confirmation of the above reasoning, I may refer to the modern delta of the river Kander in the Lake of Thun in Switzerland. The Kander formerly ran parallel to that lake, until it was artificially turned into it about the year 1713, when the government of Berne caused two parallel subterranean galleries or tunnels to be excavated through the land which separated the course of the river from the lake; a distance of nearly a mile. The Kander, on being admitted, shot with the violence of a Swiss torrent through the tunnels, burst the arches of the galleries, and formed a ravine, which is now open to the day, about fifty feet in depth. A large quantity of mud and rock was swept into the lake, and an alluvial tract was formed

of a semicircular shape, which now extends for a mile along the original shore, and projects about a quarter of that distance into the lake. Its annual advance is said to amount to several yards*, and the delta terminates in a talus, the slope of which is inclined at an angle varying between 30° and 40°. For this fact I am indebted to the observations of Lord Cole and Mr. Egerton, who at my request measured the dip in 1833.† It follows, therefore, that the strata have successively accumulated on a plane thus highly inclined; so that, if the Lake of Thun, which is 600 feet deep‡, beyond the recently formed shoal, were drained, a vertical section might be laid open, 600 feet in height, in which strata would be seen having a greater dip than those of the Magnan, yet which had remained undisturbed from the period of their original deposition.

Tertiary Strata at the eastern extremity of the Pyrenees. — I shall conclude this chapter with one more example, derived from a region not far distant. On the borders of the Mediterranean, at the eastern extremity of the Pyrenees, in the south of France, a considerable thickness of tertiary strata is seen in the valleys of the rivers Tech, Tet, and Gly. They bear much resemblance to those already described, consisting partly of a large proportion of conglomerate, and partly of clay and sand, with subordinate beds of lignite. They abut against the primary formation of the Pyrenees, which here consists of mica-schist. Between Ceret and Boulon these tertiary strata are seen inclined at an angle of between 20° and 30°.

* See a paper by the Rev. J. Yates, on Alluvium, Ed. New Phil. Journ. 1834.

† Proceedings of Geol. Soc. 1834.

‡ Mr. Yates, ibid.

The shells which I procured from several localities were recognized by M. Deshayes as agreeing with Subapennine fossils.

Spain—Morea.—It appears, from the recent observations of Colonel Silvertop, that marine strata of the Older Pliocene period occur in patches at Malaga, and in Granada, in Spain. They have also been discovered by MM. Boblaye and Virlet in the Morea.

CHAPTER XIII.

OLDER PLIOCENE FORMATIONS — CRAG.

Crag of Norfolk and Suffolk — Appears by its fossil contents to belong to the Older Pliocene period. — Divisible into coralline and red crag. — Superincumbent lacustrine deposits — Forms of stratification (p. 91.) — Oblique layers — Cause of this arrangement — Dislocations in the crag produced by subterranean movements — Protruded masses of chalk (p. 98.) — Associated alluvium.

The Older Pliocene strata, described in the last chapter, are all situated in countries bordering the Mediterranean; but there is a group in our own island, probably belonging to the same era, which I shall now consider. I have already alluded to this deposit under the provincial name of crag *, and pointed out its superposition to the London clay, a tertiary formation of much higher antiquity.† The crag is chiefly developed in the eastern parts of Norfolk and Suffolk, from whence it extends into Essex.

Its relative age. — A collection of the shells of the "crag" beds, which I formed in 1829, together with a much larger number sent me by my friend Mr. Mantell, of Lewes, were carefully examined by M. Deshayes, and compared with the tertiary species in his cabinet. This comparison gave the following re-

* Vol. III. p. 358. † See Fig. 64. Vol. III. p. 360.

sult: — out of 111 species, 66 were extinct or unknown, and 45 recent; the last, with one exception (*Voluta Lamberti*, Sow.), being now inhabitants of the German Ocean. Such being the proportion of recent and extinct species, I referred the crag, in accordance with the rules above laid down, to the Older Pliocene period.* Since that time a much larger number of organic remains has been obtained from this formation by several naturalists, especially by Mr. Wood, of Hasketon, in Suffolk; but the species have not yet been compared with those of other tertiary strata, so as to enable me to announce the general bearing of the results.

It appears, however, from a recent communication made by Mr. Charlesworth, of Suffolk, to the Geological Society, that the inferior and fossiliferous portion of the crag is divisible into two distinct masses, one of which may be termed the lower or "coralline crag," and the other the "red crag." The lower division is composed of calcareous sand, chiefly derived from decomposed corals, in which are imbedded shells, corals, and sponges, in a good state of preservation, and which must evidently have lived on the spot.

This coralline formation is almost without stratification, and in some places forms a soft stone used in building; it has not been seen to attain a greater thickness than about 12 feet, but it was not pierced through at that depth in all localities. The coralline crag rests immediately on the London clay, and may be studied at several places in Suffolk, as at Tattingstone, Ramsholt, Sudburn Park, Orford, and Aldborough.

The red crag is distinguished from the coralline, upon which it lies in some places unconformably, by

* See Vol. III. p. 391.

the deep red ferruginous or ochreous colour of its sands and fossils. It consists in great part of numerous layers of siliceous sand containing shells, which are usually broken and worn. Among these are many of the genera Buccinum and Murex, which have never been met with in the coralline crag.

Mr. Wood states that he has in his collection, exclusive of Polypi, Radiaria, and Crustacea, no less than 450 species of invertebrated animals from the crag, among which there are of annulata 13, cirrhipeda 11, conchifera 189, mollusca 257. Among the mollusca are 50 species of minute cephalopoda, of the order Forammifera of D'Orbigny, which seem peculiar to the coralline crag. In the red crag have been found 235 species of the above classes of fossils; in the coralline crag 353; about 150 species being common to the two divisions.

It must remain for future investigations to determine how far this great addition of new fossils may modify the proportional number of recent to extinct shells previously deduced from more limited data.* The greater part of the shells before examined were derived from the red crag, which is evidently a newer deposit than the coralline, although I do not anticipate that these formations will turn out to be referrible to distinct periods, as they contain so many species in common. The generic difference in the shells and other organic forms may depend on a difference of conditions, such as might exist in different parts of the sea at one and the same period. Thus we may suppose one region, where the water is deep and tranquil, to be favourable to the growth of corals, sponges, echini, and microscopic cephalopods, such as charac-

* See the note at the end of this chapter.

terize the lower crag; whilst in another and somewhat shallower region, where currents prevailed, and to which sand and shingle were often drifted, no zoophytes might exist, although certain kinds of testacea abounded. According to this hypothesis, it is conceivable that a certain space where the coralline crag was first formed became afterwards converted into a shoal, or exposed to the action of waves and currents, and was then the receptacle of deposits like the fossiliferous red crag.

The shelly beds of Norfolk appear to belong exclusively to the red crag; but on the northern limits of that county they are said to be occasionally covered by a still newer stratum, containing exclusively species now living in the adjoining sea. This is doubtless the marine formation described by Mr. Phillips as occurring throughout Holderness, in Yorkshire.* According to this view, the succession of tertiary formations, in following our eastern coast from the estuary of the Thames to that of the Humber, will be, first, in Essex, the Eocene or London clay; secondly, in Suffolk, the coralline crag, probably belonging to the Older Pliocene period; next, the red crag of Suffolk and Norfolk, also of the Older Pliocene era; and lastly, on the extreme northern boundary of Norfolk and in Holderness, a marine Newer Pliocene deposit.

Among the teeth of fish from the crag, Mr. Agassiz informs me that he has recognized many belonging to the genus Platax, a form now foreign to our northern seas, and occurring in the Indian Ocean.

The strata which occupy the larger part of the cliffs of Norfolk and Suffolk are for the most part

* See Phillips's Geol. of Yorksh.

superimposed upon the above-mentioned fossiliferous strata, and are very heterogeneous in their mineral character, consisting of sand, gravel, and blue or brown marl; the shells imbedded in the sand and marl being broken, and sometimes finely comminuted. In many places are seen alternations of sand and shingle, destitute of organic remains, and more than two hundred feet in thickness, as in the Suffolk cliffs, between Dunwich and Yarmouth. In others, we meet with an enormous mass, more than three hundred feet in thickness, of sand, loam, and clay, containing bones of terrestrial quadrupeds, and drift wood; sometimes stratified regularly, at others consisting of a confused heap of rubbish, in which fragments of the chalk and its flints are imbedded in a chalky marl.

In this aggregate are also found many fragments of older rocks, the septaria of the London clay, together with ammonites, vertebræ of ichthyosauri, and other fossils from parts of the oolitic series. It has been questioned whether all the above-mentioned beds can be considered as belonging to the same era, and the subject certainly admits of doubt; but after examining, in 1829, the whole line of coast of Essex, Suffolk, and Norfolk, I found it impossible to draw any line of separation between the different groups. Each seemed in its turn to pass into another; and those masses which approach in character to alluvium, and contain the remains of terrestrial quadrupeds, are occasionally intermixed with the strata of the crag.

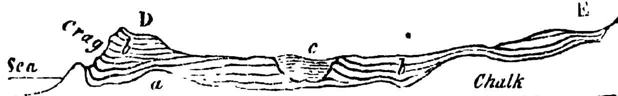
There are, however, lacustrine deposits overlying the crag, which no doubt belong to a distinct zoological period. These are found in small cavities, which must have existed on the surface of the crag after its

elevation, and which formed small lakes or ponds wherein recent fresh-water testacea were included in loamy strata. (See Fig. 94. *c*.)

Relative position. — The crag is seen to rest on the chalk and on the London clay, but more commonly on the chalk. The strata are in great part horizontal, or slightly undulating; but at some points they are much disturbed, especially where several masses of chalk appear to have been protruded from below.

The annexed section may give a general idea of

Fig. 94.



a. Chalk. *b*. Crag. *c*. Lacustrine deposit.
D. Trimmingham beacon.
E. Interior and higher part of Norfolk. *

the manner in which the crag may be supposed to rest on the chalk as we pass from the Norfolk cliffs, at Trimmingham, into the interior, where the country rises gradually.

The outline of the surface of the subjacent chalk, in this section, is imaginary, but is such as might explain the relations of those protruded masses, three of which appear in the cliffs near Trimmingham, and which some geologists have too hastily assumed to be unconnected with the great mass of chalk below I shall treat of these presently, when describing the

* This section is compiled principally from one by Mr. Murchison; the others in this chapter are from sketches which I made in 1829.

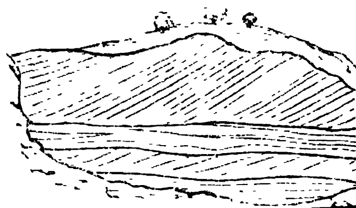
disturbances which the crag appears to have suffered since its original deposition.

In the interior, at E, there is a thick covering of sand and gravel upon the chalk, having the characters of an alluvium, partly, perhaps, marine, and partly terrestrial, and which seems to pass gradually in this district into the regular marine strata of the crag.

Forms of stratification. — In almost every formation the individual strata are rarely persistent for a great distance, the superior and inferior planes being seldom precisely parallel to each other; and if the materials are very coarse, the beds often thin out if we trace them for a few hundred yards. There are also many cases where all the layers are oblique to the general direction of the strata, and the crag affords most interesting illustrations of this phenomenon.

In the sea-cliff near Walton, in Suffolk, opposite the Martello Tower, called R, the section represented in the annexed diagram is seen. The vertical height is about 20 feet, and the beds consist alternately of sets of inclined and horizontal layers of sand and comminuted shells. The sand is siliceous, and of a fer-

Fig. 95.



Section of shelly crag near Walton, Suffolk.

ruginous colour; but the layers are sometimes made up of small plates of bivalve shells, arranged with their

flat sides parallel to the plane of each layer, like mica in micaceous sandstones.

The number of laminæ in the thickness of an inch, both in the siliceous and shelly sand, varies from seven to ten, so that it is impossible to express them all in the diagram. The height of the uppermost stratum is, in this instance, remarkable, as it extends to twelve feet. The inclination of the laminæ is about 30°; but in the cliffs of Bawdesey, to the eastward, they are sometimes inclined at an angle of 45°, and even more.

Fig. 96.



Section at the lighthouse near Happisborough. Height sixteen feet.

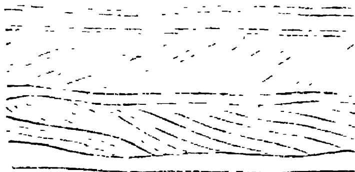
a. Pebbles of chalk flint, and of rolled pieces of white chalk.
b. Loam overlying *a*. *c, c.* Blue and brown clay.

This diagonal arrangement of the layers, sometimes called "*false* stratification," is not confined to deposits of fine sand and comminuted shells; for we find beds of shingle disposed in the same manner, as is seen in the annexed section (Fig. 96.).

The direction of the dip of the inclined layers, throughout the Suffolk coast, is so uniformly to the south, that I only saw two or three instances of a contrary nature, where the inclination was northerly. One of the best examples of this variation is exhibited in a cliff between Mismer and Dunwich (Fig. 97.) In this case, there are about six layers in the thick-

ness of an inch, and the part of the cliff represented is about six feet high.

Fig. 97.



Section of part of Little Cat cliff, composed of quartzose sand, showing the inclination of the layers in opposite directions.

Another example may be seen near Walton, where the layers, which are of extreme tenuity, consist of ferruginous sand, brown loam, and comminuted shells. It is not uncommon to find in this manner sets of perfectly horizontal strata resting upon and covered by groups of wavy and transverse layers.

Fig. 98.



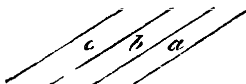
Lamination of shelly sand and loam, near the Signal-house, Walton. Vertical height four feet.

The appearances exhibited in the diagrams are not peculiar to the crag: they may be found in almost every gravel-pit; and I have seen sand and pebble-beds of all ages, including the old red sandstone, greywacké, and clay-slate, exhibit the same arrangement.

If we now inquire into the causes of such a disposition of the materials of each bed or group of layers, it

may, in the first place, be remarked, that however numerous may be the successive layers *a*, *b*, *c*, the layer *a* must have been deposited before *b*, *b* before *c*, and so of the rest.

Fig. 99.



We must suppose that each thin seam was thrown down on a slope, and that it conformed itself to the side of the steep bank, just as we see the materials of a talus arrange themselves at the foot of a cliff when they have been cast down successively from above. If the transverse layers are cut off by a nearly horizontal line, as in many of the above sections, it may arise from the denuding action of a wave which has carried away the upper portion of a submarine bank, and truncated the layers of which it was composed. But I do not conceive this hypothesis to be necessary; for if a bank have a steep side, it may grow by the successive apposition of thin strata thrown down upon its slanting side, and the removal of matter from the top may proceed simultaneously with its lateral extension. The same current may borrow from the top what it gives to the sides; a mode of formation which I had lately an opportunity of observing on the rippled surface of the hills of blown sand near Calais. The undulating ridges and intervening furrows on the dunes of blown sand resembled exactly in form those caused by the waves on a sea-beach, and were always at right angles to the direction of the wind which had produced them. Each ridge had one side slightly inclined, and

Fig. 100.



the other steep; the lee side being always steep, as *b, c, d, e;* the windward side a gentle slope, as *a, b, c, d.* When a gust of wind blew with sufficient force to drive along a cloud of sand, all the ridges were seen to be in motion at once, each encroaching on the furrow before it, and, in the course of a few minutes, filling the place which the furrows had occupied. Many grains of sand were drifted along the slopes *a b* and *c d*, which, when they fell over the scarps *b c* and *d e*, were under shelter from the wind; so that they remained stationary, resting, according to their shape and momentum, on different parts of the descent. In this manner each ridge was distinctly seen to move slowly on as often as the force of the wind augmented. We shall not strain analogy too far, by supposing that, in such cases, the same laws may govern subaqueous and subaërial phenomena; and if so, we may imagine a submarine bank to be nothing more than one of the ridges of ripple on a larger scale, which may increase in the manner before suggested, by successive additions to the steep scarps.

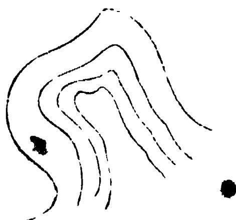
The set of tides and currents, in opposite directions, may account for sudden variations in the direction of the dip of the layers, as represented in Fig. 97.; while the general prevalence of a southerly inclination in the crag of Suffolk may indicate that the matter was brought by a current from the north.

I may refer to a drawing given in the first volume*, to show the analogy of the arrangement of the submarine strata, just considered, to that exhibited by deposits formed in the channels of rivers where a considerable transportation of sediment is in progress.

* P. 374. Fig. 10.

Derangement in the crag strata.—In the above examples I have explained the want of parallelism or horizontality in the subordinate layers of different strata, by reference to the mode of their original deposition; but there are signs of disturbance which can only be accounted for by subsequent movements. The same blue and brown clay, or loam, which is often perfectly horizontal, and as regularly bedded as any of our older formations, is, in other places, curved and even folded back upon itself, in the manner represented in the annexed diagrams.

Fig. 101.



Bent strata of loam in the cliffs between Cromer and Runton.

Fig. 102.

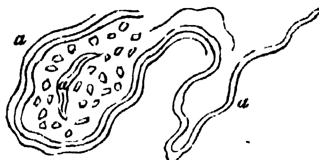


Folding of the strata between East and West Runton

In the last of these cuts a central nucleus of sand is surrounded by argillaceous and sandy layers. This phenomenon is very frequent; and there are instances where the materials thus enveloped consist of broken flints mingled with pieces of chalk, forming a white mass, encircled by dark laminated clay. The diameter of these included masses, as seen in sections laid open in the sea cliffs, varies from five to fifteen feet.

East of Sherringham, a heap of partially-rounded flints, about five feet in diameter, is nearly enveloped by finely laminated strata of sand and loam, and some of the loam is entangled in the midst of the flints.

Fig. 103.

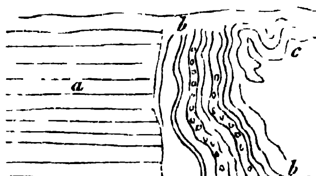


Section in the Cliffs east of Sherringham.
a. Sand and loam in thin layers.

In this and similar instances, we may imagine the yielding strata, *a*, to have subsided into a cavity, and the flints belonging to a superincumbent bed to have pressed down with their weight, so as to cause the strata to fold round them.

That some masses of stratified sand and loam have actually sunk down into cavities, or have fallen like landslips into ravines, seems indicated by other appearances. Thus, near Sherringham, the argillaceous beds, *a*, represented in the annexed diagram (Fig. 104.), are cut off abruptly, and succeeded by the vertical and contorted series *b, c*. The face of the cliff here repre-

Fig. 104.



Section east of Sherringham, Norfolk.

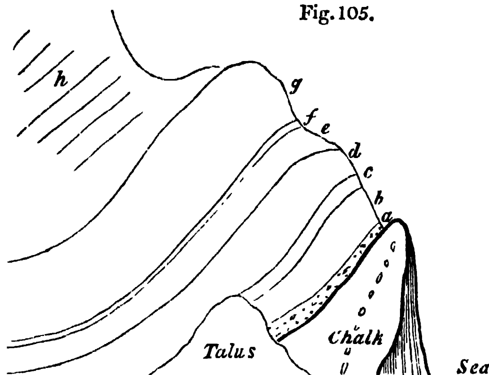
a. Sand, loam, and blue clay. b, b. Sand and gravel.
c. Twisted beds of loam.

sented is twenty-four feet in height. Some of the layers in *b, b* are composed of pebbles, and these alternate

with thin beds of loose sand. The whole set must once have been horizontal, and must have moved in a mass, or the relative position of the several parts would not have been preserved. Similar appearances may, perhaps, be produced when chasms open during earthquakes, and portions of yielding strata fall in from above and are engulphed.

Protruded masses of chalk. — But whatever opinion we may entertain on this point, we cannot doubt that subterranean movements have given rise to some of the local derangements of this formation, particularly where masses of solid chalk pierce, as it were, through

Fig. 105.



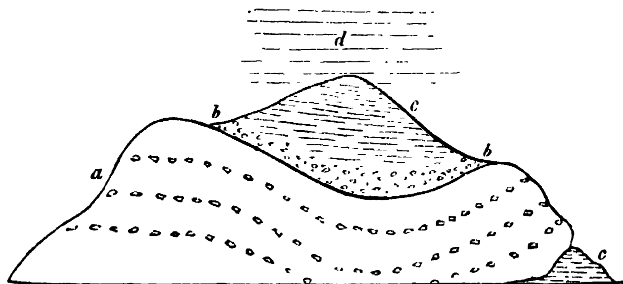
Side view of a promontory of chalk and crag, Trimmingham, Norfolk.

a. Gravel and ferruginous sand, rounded and angular pieces of chalk flint, with some quartz pebbles, 3 feet.
b. Laminated blue clay, 8 feet.
c. Yellow sand, 1 foot 6 inches.
d. Dark blue clay, with fragments of marine shells, 6 feet.
e. Yellow loam and flint gravel, 3 feet.
f. Light blue clay, 1 foot. g. Sand and loam, 12 feet.
h. Yellow and white sand, loam, and gravel, about 100 feet.

the crag. Thus, between Mundesley and Trimmingham we see the appearances exhibited in the accompanying view (Fig. 105.). The chalk, of which the strata are highly inclined, or vertical, projects in a promontory, because it offers more resistance to the action of the waves than the tertiary beds which, on both sides, constitute the whole of the cliff. The height of the soft crag strata immediately above the chalk is, in this place about 130 feet. Those which are in contact (see the wood-cut) are inclined at an angle of 45°, and appear more disturbed than in other parts of the cliffs, as if they had been displaced by the movement by which the chalk was protruded.

Very similar appearances are exhibited by the northernmost of the three protuberances of chalk, of which a front view is given in the annexed diagram. It oc-

Fig. 106.



Northern protuberance of chalk, Trimmingham.

a. Chalk with flints.
b. Gravel of broken and half-rounded flints.
c. Laminated blue clay. *d.* Sand and yellow loam.

cupies a space of about one hundred yards along the shore, and projects about sixty yards in advance of the general line of cliff. One of its edges, at *c*, rests upon

the blue clay beds of the crag, in such a manner as to imply that the mass had been undermined when the crag was deposited, unless we suppose, as some have done, that this chalk is a great detached mass enveloped by crag. For, as one of the "Needles," or insulated rocks of chalk, which stood 120 feet above high water mark, at the western extremity of the Isle of Wight, fell into the sea in 1772 *, so a pinnacle of chalk may have been precipitated into the tertiary sea, at a point where some strata of the crag had previously accumulated. The beds of flint and chalk in the above diagram appear nearly horizontal; but they are in fact highly inclined inwards towards the cliff. The rapid waste of the Norfolk coast might soon enable us to understand the true position of this mass, if observations and drawings were made from time to time of the appearances which it presents. †

Perhaps it may be necessary to suppose, that subterranean movements were in progress during the deposition of the crag; and the extraordinary dislocations of the beds, in some places, which in others are perfectly regular and horizontal, may be most easily accounted for by introducing an alternate rise and depression of the bed of the sea, such as we know to be usually attendant on a series of subterranean convulsions. Several of the contortions may also have been produced by lateral movements.

Passage of marine crag into alluvium. — By supposing the adjoining lands to have participated in this movement, we may explain the origin of those masses

* Dodsley's Annual Register, vol. xv. p. 140.

† For additional facts respecting the sections and organic remains of part of the coast above described, see Geology of Norfolk, by Samuel Woodward, 1833.

of an alluvial character which contain the detritus of many rocks, the bones of land animals, and of drift timber, which were evidently swept down into the sea. The land-floods which accompany earthquakes are, as we have seen, capable of transporting such materials to great distances; and, as part of these alluviums must be left somewhere upon the land, we may expect to find, on exploring the submarine surface when it is afterwards disclosed, a gradual passage from the terrestrial alluvium to that which was carried down into the sea, so as to alternate with marine beds.*

* While this sheet was passing through the press I received a letter from the Rev. Dr. Fleming, author of Brit. Anim ; to which I shall allude, because some imagine that the " crag " will be found to contain a larger proportion of recent species than I had formerly inferred. Dr. F. rather anticipates the contrary, for among the crag fossils examined by him he recognizes a decided plurality of species now living in the German Ocean. Thus among a small number of minute multilocular cephalopods of the crag he has seen Nautilus crispus, Rotalia beccaria, R. beccarii-perversa, Lobatula vulgaris (the sinistral var.), and Vermiculum oblongum. Out of a few zoophytes of the crag sent to him some were extinct, but he found the following recent species: Eschara retiformis, E. fascialis, Retepora reticulata, with Hornera frondiculala of Lamouroux (a Mediterranean species), Cellepora pumicosa, Berenicea utriculata, Farcimia fistulosa, Caryophyllia cyathus, and C. ramea.

CHAPTER XIV.

VOLCANIC ROCKS OF THE OLDER PLIOCENE PERIOD.

Igneous rocks of this period in Italy — Volcanic region of Olot, in Catalonia — Lava currents — Ravines — Ancient alluvium — Jets of air called "Bufadors" (p. 111.) — Age of the Catalonian volcanos uncertain — Earthquake of Olot in 1421 — Sardinian volcanos — District of the Eifel and Lower Rhine — Peculiar characteristics of the Eifel volcanos — Lake craters (p. 115.) — Trass — Age of the Eifel volcanic rocks uncertain (p. 122) — Brown coal formation.

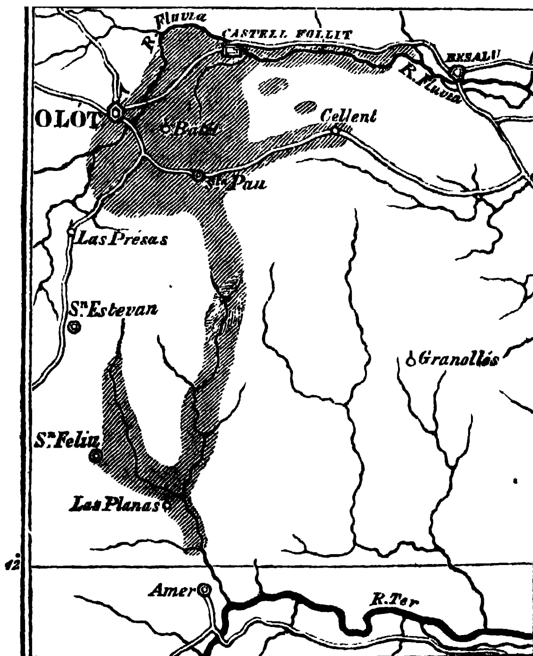
Italy.—It is part of my proposed plan to consider the igneous as well as the aqueous formations of each period; but I am far from being able as yet to assign to each of the numerous groups of volcanic origin scattered over Europe a precise place in the chronological series. It has been already stated, that the volcanic rocks of Tuscany belong, in part at least, to the Older Pliocene period, — those, for example, of Radicofani, Viterbo, and Aquapendente, which have been chiefly erupted beneath the sea. The same observation would probably hold true in regard to the igneous rocks of the Campagna di Roma.

But several other districts, of which the dates are still uncertain, may be mentioned in this chapter as being possibly referrible to the period now under consideration. It will at least be useful to explain the points which require elucidation before the exact age of the groups about to be described can be accurately determined.

Volcanos of Olot, in Catalonia.—I shall first describe a district of extinct volcanos in the north of Spain, which is little known, and which I visited in the summer of 1830.

The whole extent of country occupied by volcanic products in Catalonia is not more than fifteen geographical miles from north to south, and about six from east to west. The vents of eruption range entirely within a narrow band running north and south; and the branches, which are represented as extending

Fig. 107.



Volcanic district of Catalonia.

eastward in the map, are formed simply of two lava-streams — those of Castell Follit and Cellent.

Dr. Maclure, the American geologist, was the first who made known the existence of these volcanos * ; and, according to his description, the volcanic region extended over twenty square leagues, from Amer to Massanet. I searched in vain in the environs of Massanet, in the Pyrenees, for traces of a lava-current ; and I can say, with confidence, that the adjoined map gives a correct view of the true area of the volcanic action.

Geological structure of the district. — The eruptions have burst entirely through secondary rocks, composed in great part of grey and greenish sandstone and conglomerate, with some thick beds of nummulitic limestone. The conglomerate contains pebbles of quartz, limestone, and Lydian stone. The limestone is not only replete with nummulites, but occasionally includes oysters, pectens, and other shells. This system of rocks is very extensively spread throughout Catalonia; one of its members being a red sandstone, to which the celebrated salt-rock of Cardona is subordinate. It is conjectured that the whole belongs to the age of our green-sand and chalk.

Near Amer, in the Valley of the Ter, on the southern borders of the region delineated in the map, primary rocks are seen consisting of gneiss, mica-schist, and clay-slate. They run in a line nearly parallel to the Pyrenees, and throw off the secondary strata from their flanks, causing them to dip to the north and north-west. This dip, which is towards the Pyrenees, is connected with a distinct axis of elevation, and pre-

* Maclure, Journ. de Phys., vol. lxvi. p. 219., 1808; cited by Daubeny, Description of Volcanos, p. 24.

vails through the whole area described in the map, the inclination of the beds being sometimes at an angle of between 40 and 50 degrees.

It is evident that the physical geography of the country has undergone no material change since the commencement of the era of the volcanic eruptions, except such as has resulted from the introduction of new hills of scoriæ, and currents of lava upon the surface. If the lavas could be remelted and poured out again from their respective craters, they would descend the same valleys in which they are now seen, and re-occupy the spaces which they at present fill. The only difference in the external configuration of the fresh lavas would consist in this, that they would nowhere be intersected by ravines, or exhibit marks of erosion by running water.

Volcanic cones and lavas. — There are about fourteen distinct cones with craters in this part of Spain, besides several points whence lavas may have issued; all of them arranged along a narrow line running north and south, as will be seen in the map. The greatest number of perfect cones are in the immediate neighbourhood of Olot, some of which are represented in the annexed plate (Pl. XI.); and the level plain on which that town stands has clearly been produced by the flowing down of many lava-streams from those hills into the bottom of a valley, probably once of considerable depth, like those of the surrounding country.

In this Plate an attempt is made to represent by colours the different geological formations of which the country is composed.* The blue line of moun-

* This view is taken from a sketch which I made on the spot in 1830.

tains in the distance are the Pyrenees, which are to the north of the spectator, and consist of primary and ancient secondary rocks. In front of these are the secondary formations described in this chapter, coloured grey. Different shades of this colour are introduced, to express various distances. The flank of the hill, in the foreground, called Costa de Pujou, is composed partly of secondary rocks, and partly of volcanic, the red colour expressing lava and scoriæ.

The Fluvia, which flows near the town of Olot, has cut to the depth of only 40 feet through the lavas of the plain before mentioned. The bed of the river is hard basalt; and at the bridge of Santa Madalena are seen two distinct lava-currents, one above the other, separated by a horizontal bed of scoriæ eight feet thick.

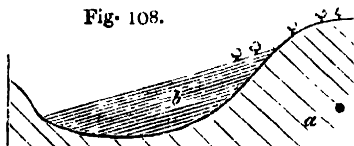
In one place, to the south of Olot, the even surface of the plain is broken by a mound of lava, called the "Bosque de Tosca," the upper part of which is scoriaceous, and covered with enormous heaps of fragments of basalt more or less porous. Between the numerous hummocks thus formed are deep cavities, having the appearance of small craters. The whole precisely resembles some of the modern currents of Etna, or that of Côme, near Clermont; the last of which, like the Bosque de Tosca, supports only a scanty vegetation.

Most of the Catalonian volcanos are as entire as those in the neighbourhood of Naples, or on the flanks of Etna. One of these, figured in the plate, called Montsacopa, is of a very regular form, and has a circular depression or crater at the summit. It is chiefly made up of red scoriæ, undistinguishable from that of the minor cones of Etna. The neighbouring hills of Olivet and Garrinada, also figured in the plate, are of

similar composition and shape. The largest crater of the whole district occurs farther to the east of Olot, and is called Santa Margarita. It is 455 feet deep, and about a mile in circumference. Like Astroni, near Naples, it is richly covered with wood, wherein game of various kinds abounds.

Although the volcanos of Catalonia have broken out through sandstone, shale, and limestone, as have those of the Eifel, in Germany, to be described in the sequel, there is a remarkable difference in the nature of the ejections composing the cones in these two regions. In the Eifel, the quantity of pieces of sandstone and shale thrown out from the vents is often so immense as far to exceed in volume the scoriæ, pumice, and lava ; but I sought in vain in the cones near Olot for a single fragment of any extraneous rock; and Don Francisco Bolos, an eminent botanist of Olot, informs me that he has never been able to detect any. Volcanic sand and ashes are not confined to the cones, but have been sometimes scattered by the wind over the country, and drifted into narrow valleys, as is seen between Olot and Cellent, where the annexed section is exposed. The light cindery volcanic matter rests in thin regular layers, just as it alighted on the slope formed by the solid conglomerate. No flood could

Fig. 108.

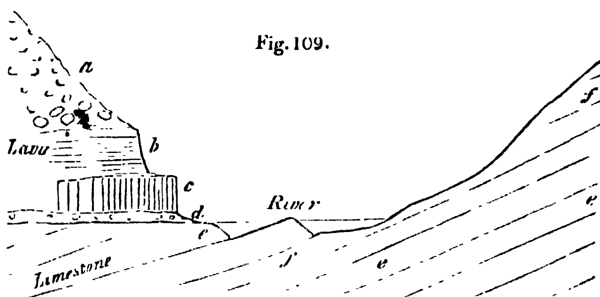


a. Secondary conglomerate.
b. Thin seams of volcanic sand and scoriæ.

have passed through the valley since the scoriæ fell, or these would have been for the most part removed.

The currents of lava in Catalonia, like those of

Auvergne, the Vivarais, Iceland, and all mountainous countries, are of considerable depth in narrow defiles, but spread out into comparatively thin sheets in places where the valleys widen. If a river has flowed on nearly level ground, as in the great plain near Olot, the water has only excavated a channel of slight depth; but where the declivity is great, the stream has cut a deep section, sometimes by penetrating directly through the central part of a lava-current, but more frequently by passing between the lava and the secondary rock which bounds the valley. Thus, in the accompanying section, at the bridge of Cellent, six miles east of Olot,



Section above the bridge of Cellent.

a. Scoriaceous lava.
b. Schistose basalt.
c. Columnar basalt.
d. Scoriæ, vegetable soil, and alluvium.
e. Nummulitic limestone.
f. Micaceous grey sandstone.

we see the lava on one side of the small stream; while the inclined stratified rocks constitute the channel and opposite bank. The upper part of the lava at that place, as is usual in the currents of Etna and Vesuvius, is scoriaceous; farther down it becomes less porous, and assumes a spheroidal structure; still lower it divides in horizontal plates, each about two inches in

thickness, and is more compact. Lastly, at the bottom is a mass of prismatic basalt about five feet thick. The vertical columns often rest immediately on the subjacent secondary rocks; but there is sometimes an intervention of such sand and scoriæ as cover the country during volcanic eruptions, and which when unprotected, as here, by superincumbent lava, is washed away from the surface of the land. Sometimes, the bed *d* contains a few pebbles and angular fragments of rock; in other places fine earth, which may have constituted an ancient vegetable soil.

In several localities, beds of sand and ashes are interposed between the lava and subjacent stratified rock, as may be seen if we follow the course of the lava-current which descends from Las Planas towards Amer, and stops two miles short of that town. The river there has often cut through the lava, and through eighteen feet of underlying limestone. Occasionally an alluvium, several feet thick, is interspersed between the igneous and marine formation; and it is interesting to remark that in this, as in other beds of pebbles occupying a similar position, there are *no* rounded fragments of lava; whereas, in the most modern gravel-beds of rivers of this country, volcanic pebbles are abundant.

The deepest excavation made by a river through lava, which I observed in this part of Spain, is that seen in the bottom of a valley near San Feliu de Pallerôls, opposite the Castell de Stolles. The lava there has filled up the bottom of a valley, and a narrow ravine has been cut through it to the depth of one hundred feet. In the lower part the lava has a columnar structure. A great number of ages were probably required for the erosion of so deep a ravine;

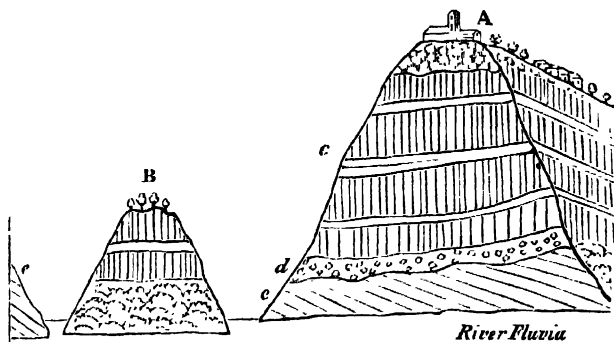
but we have no reason to infer that this current is of higher antiquity than those of the plain near Olot. The fall of the ground, and consequent velocity of the stream, being in this case greater, a more considerable volume of rock may have been removed in the same time.

I shall describe one more section to elucidate the phenomena of this district. A lava-stream, flowing from a ridge of hills on the east of Olot, descends a considerable slope, until it reaches the valley of the river Fluvia. Here, for the first time, it comes in contact with running water, which has removed a portion, and laid open its internal structure in a precipice about 130 feet in height, at the edge of which stands the town of Castell Follit.

By the junction of the rivers Fluvia and Teronel the mass of lava has been cut away on two sides; and the insular rock B (Fig. 110.) has been left, which was probably never so high as the cliff A, as it may have constituted the lower part of the sloping side of the original current.

From an examination of the vertical cliffs, it appears that the upper part of the lava on which the town is built is scoriaceous, passing downwards into a spheroidal basalt; some of the huge spheroids being no less than six feet in diameter. Below this is a more compact basalt with crystals of olivine. There are in all about four distinct ranges of prismatic basalt, separated by thinner beds not columnar, and some of which are schistose. The whole mass rests on alluvium. ten or twelve feet in thickness, composed of pebbles of limestone and quartz, but without any intermixture of igneous rocks; in which circumstance alone it appears to differ from the modern gravel of the Fluvia.

Fig. 110.



Section at Castell Follit.

A. Church and town of Castell Follit, overlooking precipices of basalt.
B. Small island, on each side of which branches of the river Teronel flow to meet the Fluvia.
c. Precipice of basaltic lava, chiefly columnar, about 130 feet in height.
d. Ancient alluvium underlying the lava-current.
e. Inclined strata of secondary sandstone.

Bufadors.—The volcanic rocks near Olot have often a cavernous structure, like some of the lavas of Etna; and in many parts of the hill of Batet, in the environs of the town, the sound returned by the earth, when struck, is like that of an archway. At the base of the same hill are the mouths of several subterranean caverns, about twelve in number, which are called in the country "bufadors," from which a current of cold air issues during summer, but which in winter is said to be scarcely perceptible. I visited one of these bufadors in the beginning of August, 1830, when the heat of the season was unusually intense, and found a cold wind blowing from it; which may easily be ex-

plained; for as the external air, when rarefied by heat, ascends, the pressure of the colder and heavier air of the caverns in the interior of the mountain causes it to rush out to supply its place.

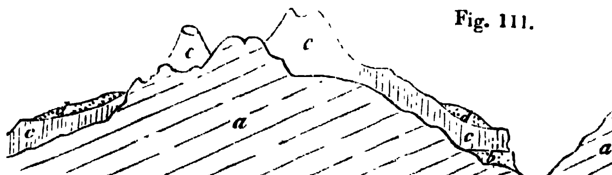
Age of the Catalonian volcanos uncertain. — It now only remains to offer some remarks on the probable age of these Spanish volcanos. Attempts have been made to prove, that in this country, as well as in Auvergne and the Eifel, the earliest inhabitants were eyewitnesses to the volcanic action. In the year 1421, it is said, when Olot was destroyed by an earthquake, an eruption broke out near Amer, and consumed the town. The researches of Don Francisco Bolos have, I think, shown, in the most satisfactory manner, that there is no good historical foundation for the latter part of this story; and any geologist who has visited Amer must be convinced that there never was any eruption on that spot. It is true, that, in the year above mentioned, the whole of Olot, with the exception of a single house, was cast down by an earthquake; one of those shocks which, at distant intervals during the last five centuries, have shaken the Pyrenees, and particularly the country between Perpignan and Olot, where the movements, at the period alluded to, were most violent.

Some houses are said to have sunk into the earth; and this account has been corroborated by the fact that, within the memory of persons now living, the buried arches of a Benedictine monastery were found at a depth of six feet beneath the surface; and still later, some houses were dug out in the street called Aigua. Don Bolos informed me, that he was present when the latter excavation was made, and when the roof of a buried house was found nearly entire; the

interior of the building being in a great part empty, so that it was necessary to fill it up with earth and stones, in order to form a sure foundation for the new edifice.

The annihilation of the ancient Olot may, perhaps, be ascribed, not to the extraordinary violence of the movement on that spot, but to the cavernous nature of the subjacent rocks; for Catalonia is beyond the line of those European earthquakes which have, within the period of history, destroyed towns throughout extensive areas.

As we have no historical records, then, to guide us in regard to the extinct volcanos, we must appeal to geological monuments. I have little doubt that some fossil land-shells, and bones of quadrupeds, will hereafter reward the industry of collectors. If such remains are found imbedded in volcanic ejections, the period of the eruptions may be inferred; but at present we have no evidence beyond that afforded by superposition, in regard to which the annexed diagram will present to the reader, in a synoptical form, the results obtained from numerous sections.



Superposition of rocks in the volcanic district of Catalonia

a. Sandstone and nummulitic limestone.
b. Older alluvium without volcanic pebbles.
c. Cones of scoriæ and lava. *d.* Newer alluvium.

The more modern alluvium, *d*, is partial, and has been formed by the action of rivers and floods upon the

lava; whereas the older gravel, *b*, was strewed over the country before the volcanic eruptions. In neither have any organic remains been discovered; so that we can merely affirm, as yet, that the volcanos broke out after the elevation of some of the newest rocks of the secondary series, and before the formation of an alluvium, *d*, of unknown date. The integrity of the cones merely shows that the country has not been agitated by violent earthquakes, or subjected to the action of any great transient flood since their origin.

East of Olot, on the Catalonian coast, marine tertiary strata occur, which, near Barcelona, attain the height of about five hundred feet. It appears probable, from a small number of shells which I collected, that these strata may correspond with the Subapennine beds; so that if the volcanic district had extended thus far, we might be able to determine the age of the igneous products, by observing their relation to these Older Pliocene formations.*

Sardinian volcanos.—The line of extinct volcanos in Sardinia, described by Captain Smyth†, is also of uncertain date, as, notwithstanding the freshness of some of the cones and lavas, they may be of high antiquity. They rest, however, on a tertiary formation, supposed by some to correspond to the Subapennine strata, but of which the fossil remains have not been fully described.

Volcanic rocks of the Eifel.—The volcanos of the Lower Rhine and the Eifel are, for the most part, of no

* For some account of the Olot volcanos, see "Noticia de los Estinguidos Volcanes de la Villa de Olot," by Francisco Bolos. Barcelona. No date; but the observations, I am told, preceded those of Dr. Maclure.

† Present State of Sardinia, &c. pp. 69, 70.

less uncertain date than those of Catalonia; but I am desirous of pointing out some of their peculiar characters, and shall, therefore, treat of them in this chapter, trusting that future investigations will determine their chronological relations more accurately.

For the geographical details of this volcanic region the reader is referred to the annexed map (Fig. 112.), for which I am indebted to Mr. Horner, whose residence in the country has enabled him to verify the maps of MM. Noeggerath and Von Oeynhausen, from which that now given has been principally compiled.

There has been a long succession of eruptions in this country, and some of them must have occurred when its physical geography was in a very different state, while others have happened when the whole district had nearly assumed its present configuration.

The fundamental rock of the Eifel is an ancient secondary sandstone and shale, to which the obscure and vague appellation of "greywacké" has been given. The formation has precisely the characters of a great part of those gray and red sandstones and shales, which are called "old red sandstone" in England and Scotland, where they constitute the inferior member of the carboniferous series. In the Eifel they occupy the same geological position, and in some parts alternate with a limestone, containing trilobites and other fossils of our "mountain" and "transition" limestones. The strata are inclined at all angles, from the horizontal to the vertical, and must have undergone reiterated convulsions before the country was moulded into its present form.

Lake-craters.—The volcanos have broken out sometimes at the bottom of deep valleys, sometimes on the summit of hills, and frequently on intervening

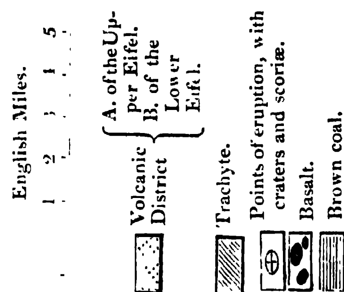


Fig. 112.

N. B. The country in that part of the map which is left blank is almost entirely composed of greywacké.

platforms. The traveller often falls upon them unexpectedly in a district otherwise extremely barren of geological interest. Thus, for example, he might arrive at the village of Gemund, immediately south of Daun, without suspecting that he was in the immediate vicinity of some of the most remarkable vents of eruption. Leaving a stream, which flows at the bottom of a deep valley in a sandstone country, he climbs the steep acclivity of a hill, where he observes the edges of strata of sandstone and shale dipping inwards to-

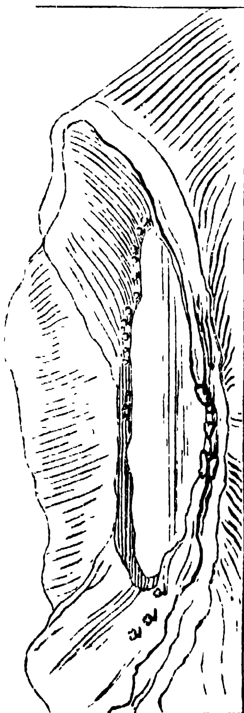


Fig. 113.

The Gemunder Maar



Fig. 114.

a. Village of Gemund. *b.* Gemunder Maar. *c.* Weinfelder Maar. *d.* Schalkenmehren Maar.

wards the mountain. When he has ascended to a considerable height, he sees fragments of scoriæ sparingly scattered over the surface; till at length, on reaching the summit, he finds himself suddenly on the edge of a *tarn*, or deep circular lake-basin.

This, which is called the Gemunder Maar, is the first of three lakes which are in immediate contact, the same ridge forming the barrier of two neighbouring cavities (see Fig. 113.). On viewing the first of these we recognize the ordinary form of a crater, for which we have been prepared by the occurrence of scoriæ scattered over the surface of the soil. But on examining the walls of the crater, we find precipices of sandstone and shale which exhibit no signs of the action of heat; and we look in vain for those beds of lava and scoriæ, dipping in opposite directions on every side, which we have been accustomed to consider as characteristic of volcanic craters. As we proceed, however, to the opposite side of the lake, and afterwards visit the craters *c* and *d* (Fig. 114.), we find a considerable quantity of scoriæ and some lava, and see the whole surface of the soil sparkling with volcanic sand, and strewed with ejected fragments of half-fused shale, which preserves its laminated texture in the interior, while it has a vitrified or scoriform coating.

A few miles to the south of the lakes above mentioned occurs the Pulvermaar of Gillenfeld, an oval lake of very regular form, and surrounded by an unbroken ridge of fragmentary materials, consisting of ejected shale and sandstone, and preserving a uniform height of about 150 feet above the water. The side slope in the interior is at an angle of about forty-five degrees; on the exterior, of thirty-five degrees. Volcanic substances are intermixed very sparingly with

the ejections, which in this place entirely conceal from view the stratified rocks of the country.*

The Meerfelder Maar is a cavity of far greater size and depth, hollowed out of similar strata; the sides presenting some abrupt sections of inclined secondary rocks, which in other places are buried under vast heaps of pulverized shale. I could discover no scoriæ amongst the ejected materials, but balls of olivine and other volcanic substances are mentioned as having been found.† This cavity, which we must suppose to have discharged an immense volume of gas, is nearly a mile in diameter, and is said to be more than one hundred fathoms deep. In the neighbourhood is a mountain called the Mosenberg, which consists of red sandstone and shale in its lower parts, but supports on its summit a triple volcanic cone, while a distinct current of lava is seen descending the flanks of the mountain. The edge of the crater of the largest cone reminded me much of the form and characters of that of Vesuvius.

If we pass from the Upper to the Lower Eifel, we find the celebrated lake-crater of Laach, which has a greater resemblance than any of those before mentioned to the Lago di Bolsena, and others in Italy — being surrounded by a ridge of gently sloping hills, composed of loose tuffs, scoriæ, and blocks of a variety of lavas.

One of the most interesting volcanos on the left bank of the Rhine is called the Roderberg. It forms a circular crater nearly a quarter of a mile in diameter, and one hundred feet deep, now covered with fields of

* Scrope, Edin. Journ. of Sci., June, 1826, p. 145.

† Hibbert, Extinct Volcanos of the Rhine, p. 24.

corn. The highly inclined greywacké strata rise even to the rim of one side of the crater; but they are overspread by quartzose gravel, and this again is covered by volcanic scoriæ and tufaceous sand. The opposite wall of the crater is composed of cinders and scorified rock, like that at the summit of Vesuvius. It is quite evident that the eruption in this case burst through the greywacké and alluvium which immediately overlies it; and I observed some of the quartz pebbles mixed with scoriæ on the flanks of the mountain, as if they had been cast up into the air, and had fallen again with the volcanic ashes.

I have already observed, that a large part of this crater has been filled up with loess, and I have pointed out how far we may thus obtain a relative date for the period of its eruption.*

The most striking peculiarity of a great many of the craters above described, is the absence of any signs of alteration or torrefaction in their walls, when these are composed of regular strata of greywacké-sandstone and shale. It is evident that the summits of hills formed of the above mentioned stratified rocks have, in some cases, been carried away by gaseous explosions, while at the same time no lava, and often a very small quantity only of scoriæ has escaped from the newly formed cavity. There is, indeed, no feature in the Eifel volcanos more worthy of note, than the proofs they afford of very copious aëriform discharges, unaccompanied by the pouring out of melted matter, except here and there, in very insignificant volume. I have seen no assemblage of extinct volcanos in France, Italy, or Spain, where gaseous explosions of such magnitude

* See p. 48.

have been attended by the emission of so small a quantity of lava. Yet I looked in vain in the Eifel for any appearances which could lend support to the hypothesis, that the sudden rushing out of such enormous volumes of gas had ever lifted up the stratified rocks immediately around the vent, so as to form conical masses, having their strata dipping outwards on all sides from a central axis. In the Gemunder Maar the beds, as before stated, have an inward dip on one side of the hill; and in the walls of this and other craters, there are strata which are inclined at all angles, just as may be observed in the greywacké, far from the points of eruption. Those who favour the theory of the elevation crater might naturally expect, that in a district where so many tremendous explosions have occurred, they would find masses of greywacké towering several thousand feet above the surrounding platform, whereas the height of these ancient rocks has not been visibly affected by the sites of the extinct volcanos.*

Trass and its origin. — It appears that in the Lower Eifel eruptions of trachytic lava preceded the emission of currents of basalt, and that immense quantities of pumice were thrown out wherever trachyte issued. In this district, also, we find the tufaceous alluvium of the Rhine volcanos called *trass*, which has covered large areas, and choked up some valleys now partially re-excavated. This trass is unstratified; and its base consists almost entirely of pumice, in which are included fragments of basalt and other lavas, pieces of burnt shale, slate, and sandstone, and numerous trunks and branches of trees.

* See Vol. II. p. 205.

We may easily conceive the manner of its origin, if we reflect on what would happen if an eruption, attended by a copious evolution of gases, should now occur in one of the lake basins. The water might remain for weeks in a state of violent ebullition, until it became of the consistency of mud, just as the sea continued to be charged with red mud round Graham's Island, in the Mediterranean, in the year 1831.* If a breach should then be made in the side of the cone, the flood would sweep away great heaps of ejected fragments of shale and sandstone, which would be borne down into the adjoining valleys. Forests might be torn up by such a flood ; and thus the occurrence of the numerous trunks of trees dispersed irregularly through the trass, can be explained.

Age of the volcanic rocks. — It will be seen by the map (Fig. 112.), that the volcanic rocks extend also to the opposite or right bank of the Rhine, where they are spread over parts of the Westerwald, and form the great mass of the mountains called the Siebengebirge. They consist partly of basaltic and partly of trachytic lavas, the latter description being, in general, the more ancient of the two. There are many varieties of trachyte, some of which are highly crystalline, resembling a coarse-grained granite, with large separate crystals of felspar. Trachytic tuff is also very abundant. It is a difficult task to determine the age of all these igneous rocks, although their position, relatively to the stratified formations with which they are associated, has been clearly made out. The accompanying table presents in a synoptical view the series of rocks of the district delineated in the map (Fig. 112.).

* See Vol. II. p. 200.

a. Volcanic. *b.* Loess. *c.* Gravel. *b.* Loess. *a.* Volcanic.	A. Newer Pliocene.
d. Volcanic. *e.* Gravel. *f.* Brown coal. *g.* Volcanic. *f.* Brown coal.	B. Tertiary — of uncertain periods, but older than A.
Greywacké.	C.

It will be seen that the greywacké C, before alluded to (p. 115.), is the lowest rock of the series, which is usually in highly inclined strata; upon this reposes a nearly horizontal tertiary formation *f*, which has been called "brown coal." This deposit consists of beds of loose sand and sandstone, clay with nodules of clay-ironstone, and siliceous conglomerate. Beds of light brown and sometimes black lignite, of various thickness, are interstratified with the clays and sands, and often irregularly diffused through them. They are extensively worked for fuel, and hence the name given to the whole formation: they contain numerous impressions of leaves and stems of trees. In several places layers of trachytic tuff are interstratified, and in these tuffs are leaves of plants identical with those found in the brown coal, showing that during the period of the accumulation of the latter, some volcanic products (*g*) were ejected.

A vast deposit of gravel, *e*, chiefly composed of pebbles of white quartz, but containing also a few fragments of other rocks, lies over the brown coal formation, forming sometimes only a thin covering, at others attaining a thickness of more than 100 feet.

This gravel is very distinct in character from that now forming the bed of the Rhine. It is called "Kiesel gerolle" by the Germans, often reaches great elevations, and is covered in several places with volcanic ejections. It is evident that the country has undergone great changes in its physical geography since this gravel was formed, whereas no inconsiderable proportion of the volcanic rocks, *d*, were produced after the country had nearly attained its present configuration.

The aqueous and igneous formations above enumerated, constituting the group B, may be declared to be tertiary, from the character of the organic remains of the brown coal *f*; for they are seen to be either of the same age as *f*, or newer, and the members of the group A have been shown to be so intimately connected with the loess *, that we may, without hesitation, declare them to belong to the Newer Pliocene period. It should be recollected, however, that the whole series A only forms, in the aggregate, a very insignificant feature in the district, and the great mass of the volcanic products, *d*, may, possibly, belong to the Older Pliocene, or some still more remote era.

The varieties of wood found in the brown coal strata are said to belong entirely to dicotyledonous trees; but among the impressions of leaves, collected by Mr. Horner, some were referred by Mr. Lindley to a palm, and others resembled the Cinnamomum dulce, and Podocarpus macrophylla, which would also indicate a warm climate.†

The other organic remains of the brown coal are

* See pp. 46. 48.
† Proceedings of Geol. Soc., 1833. p. 469.

principally fishes; they are found in a bituminous shale, called paper-coal, from being divisible into extremely thin leaves. The individuals are extremely numerous; but they appear to belong to about five species, which M. Agassiz informs me are all extinct, and hitherto peculiar to this brown coal. They belong to the fresh-water genera Leuciscus, Aspius, and Perca. The remains of frogs also, of an extinct species, have been discovered in the paper coal; and a complete series may be seen in the museum at Bonn, from the most imperfect state of the tadpole to that of the full-grown animal. With these a salamander, scarcely distinguishable from the recent species, has been found, and several remains of insects.

The brown coal was evidently a fresh-water formation; but the extreme rarity of shells renders it difficult to form any conjecture as to the subdivision of the tertiary period to which it may belong. Near Marienforst, in the vicinity of Bonn, large blocks are found of a white opaque chert, containing numerous casts of fresh-water shells, which appear to belong to Planorbis rotundatus and Limnea longiscata, two species common both to the Eocene and Miocene periods, but which have not been found in any newer deposits. M. Deshayes, to whom I showed the specimens, said he felt as confident of the above identifications as *mere casts* would warrant. These blocks of chert are not *in situ*, but they probably belong to the brown coal formation, of which the hills at Marienforst consist. The brown coal is well known to contain, at other places, subordinate beds of silex. It is to be hoped, that a comparison of the organic remains of the brown coal with those of the tertiary formation of

Mayence, which appears to be of Miocene date, will throw some light on the chronological relations of the igneous and freshwater formations above considered.*

* For fuller details consult Noeggerath's Rheinland Westphalen, Memoirs of Von Dechen, Oeynhausen, and Von Buch, Steininger (erloschenen Vulkane in der Eifel, &c., Mainz, 1820), Van der Wyck (Uebersicht der Rheinischen und Eifeler erlosch. Vulkane, Bonn. 1826), Scrope (Edin. Journ. of Sci. 1826, p. 145.), Daubeny (Volcanos, p. 45.), Leonhard (Ueber Basalt-Gebilde), Hibbert (Extinct. Volcs. of Rhine), and the Memoir above cited by Mr. Horner.

CHAPTER XV.

MIOCENE FORMATIONS — MARINE.

Miocene period — Marine formations — Faluns of Touraine — compared to the English crag — Basin of the Gironde and Landes — Fresh-water limestone of Saucats, (p. 134.)—Eocene strata in the Bordeaux basin. — Position of the limestone of Blaye — Inland cliff near Dax — Montpellier — Strata of Piedmont — Superga — Valley of the Bormida — Molasse of Switzerland, (p. 140.) — Basin of Vienna — Styria — Hungary — Volhynia and Podolia — Mayence.

HAVING treated in the preceding chapters of the older and Newer Pliocene formations, I shall next consider those members of the tertiary series for which I have proposed the name of Miocene. The distinguishing characters of this group, as derived from its imbedded fossil testacea, have been explained in the fifth chapter.* In regard to the relative *position* of the strata, they underlie the Older Pliocene, and overlie the Eocene formations, when any of these happen to be present.

The area covered by the marine, fresh-water, and volcanic rocks of the Miocene period, in different parts of Europe, can already be proved to be very considerable; for they occur in Touraine, in the basin of the Loire, and still more extensively in the South of France,

* Vol. III. p. 392.

between the Pyrenees and the Gironde. They have also been observed in Piedmont, near Turin, and in the neighbouring valley of the Bormida, where the Apennines branch off from the Alps. They are largely developed in the neighbourhood of Vienna and in Styria; they abound in parts of Hungary; and they overspread extensive tracts in Volhynia and Podolia.

Shells characteristic of the Miocene strata are found in all these countries, figures of some of which are given in Plate XII., the species here selected abounding in almost all the deposits of this era, and not occurring in any Eocene or Pliocene formations. Cardita Ajar, however, is also a recent species, but has been admitted on account of its abundance in Miocene strata, and because it has never yet been observed in any *Pliocene* deposit, and is confined in a living state to tropical countries, as Senegal.

I shall now proceed to notice briefly some of the countries before enumerated as containing monuments of the era under consideration.

Touraine. — I have already alluded to the proofs of superposition adduced by M. Desnoyers, to show that the shelly strata provincially called "the Faluns of the Loire," were posterior to the most recent freshwater formation of the basin of the Seine. Their position, therefore, shows that they are of newer origin than the Eocene strata,—more recent, at least, than the uppermost beds of the Paris basin. But an examination of their fossil contents proves also that they are referrible to that type which distinguishes the Miocene period. When 300 of the Touraine shells collected by M. Desnoyers were compared by M. Deshayes with more than 1100 of the Parisian species, there were scarcely more than 20 which could

be identified; and on the other hand, the fossil shells of the Touraine beds agree far less with the testacea now inhabiting our seas than do the shells of the Older Pliocene strata of Northern Italy.

It is not merely in the basin of the Loire that the superposition of the Miocene to the Eocene strata has been observed; but in the Cotentin (see Map, chap. xx.), and in the environs of Rennes in Brittany.

The Miocene strata of the Loire have been observed to repose on a great variety of older rocks between Sologne and the sea, in which line they are seen to rest successively upon gneiss, clay-slate, coal-measures, Jura limestone, greenstone, chalk, and lastly upon the upper fresh-water deposits of the basin of the Seine. They consist principally of quartzose gravel, sand, and broken shells. The components are generally incoherent, but sometimes agglutinated together by a calcareous or earthy cement, so as to serve as a building stone. Like the shelly portion of the crag of Norfolk and Suffolk, the *faluns* and associated strata are of slight thickness, not exceeding seventy feet. They often bear a close resemblance to the crag in appearance, the shells being stained of the same ferruginous colour, and being in the same state of decay; serving in Touraine, just as in Norfolk and Suffolk, to fertilize the arable land. Like the crag, also, they contain mammiferous remains, which are not only intermixed with marine shells, but sometimes encrusted with serpulæ, flustra, and balani. These terrestrial quadrupeds belong to the genera Mastodon, Rhinoceros, Hippopotamus, &c., the assemblage, considered as a whole, being very distinct from those of the Paris gypsum.*

* Desnoyers, Bull. de la Soc. Géol. de France, tom. ii. p. 443.

The faluns and contemporary strata of the basin of the Loire may be considered generally as having been formed in a shallow sea, into which a river, flowing perhaps from some of the lands now drained by the Loire, introduced from time to time fluviatile shells, wood, and the bones of quadrupeds, which may have been washed down during floods. Some of these bones have precisely the same black colour as those found in the peaty shell-marl of Scotland; and we might imagine them to have been dyed black in *Miocene peat*, which was swept down into the sea during the waste of cliffs, did we not find the remains of cetacea in the same strata—bones, for example, of the lamantine, morse, sea-calf, and dolphin, having precisely the same colour.

The resemblance which M. Desnoyers has pointed out as existing between the English *crag* and the French *faluns* is one which ought by no means to induce us to ascribe a contemporaneous origin to these two groups, but merely a similarity of geographical circumstances at the respective periods when each was deposited. In every age, where there is land and sea, there must be shores, shallow estuaries, and rivers; and near the sea-coasts banks of marine shells and corals may accumulate. It must also be expected that rivers will drift in fresh-water shells, together with sand and pebbles, and occasionally, perhaps, sweep down the carcasses of land quadrupeds into the sea. If the sand and shells, both of the "crag" and "faluns," have each acquired the same ferruginous colour, such a coincidence would merely lead us to infer that, at each period, there happened to be springs charged with iron, which flowed into some part of the

sea or basin of the river, by which the sediment was carried down into the sea.

Even had the French and English strata which we are comparing shared a greater number of mineral characters in common, that identity could not have justified us in inferring the synchronous date of the two groups, where the discordance of fossil remains is so marked. The argument which infers a contemporaneous origin from correspondence of mineral contents, proceeds on the supposition that the materials were either washed down from a common source, or, being derived from different sources, were mingled together in a common receptacle. If, according to the latter hypothesis, the crag and the faluns were thrown down in one continuous sea, the testacea could not have been so distinct in two regions not more distant from each other than Essex and the mouth of the Loire, unless we assume that the laws which regulated the geographical distribution of species were then very different from those now prevailing. But if it be said that the two basins may have been separated from each other, as are those of the Mediterranean and Red Sea, by an isthmus, and that distinct assemblages of species may have flourished in each, as is now actually the case in those two seas *, I may reply, that such narrow lines of demarcation are extremely rare now, and must have been infinitely more so in remoter tertiary epochs; because there can be no doubt that the proportion of land to sea has been greatly on the increase in European latitudes during the more modern geological eras.

In the *faluns*, and in certain groups of the same age,

* See above, chap. x.

which occur not far to the west of Orleans, M. Desnoyers has discovered the following mammiferous quadrupeds:—*Palæotherium magnum*, *Mastodon angustidens*, *Hippopotamus major* and *H. minutus*, *Rhinoceros leptorhinus* and *R. minutus*, *Tapir gigas*, *Anthracotherium* (small species), *Sus*, *Equus* (small species), *Cervus*, and an undetermined species of the Rodentia.

The first species on this list is common to the Paris gypsum, and is therefore an example of a land quadruped common to the Miocene and Eocene formations, an exception perfectly in harmony with the results obtained from the study of fossil shells.*

Basin of the Gironde and district of the Landes.—A great extent of country between the Pyrenees and the Gironde is overspread by tertiary deposits, which have been more particularly studied in the environs of Bordeaux and Dax, from whence about six hundred species of shells have been obtained. These shells belong to the same zoological type as those of Touraine.†

Most of the beds near Dax, whence these shells are procured, consist of incoherent quartzose sand, mixed for the most part with calcareous matter, which has often bound together the sand into concretionary nodules. A great abundance of fluviatile shells occurs in many places intermixed with the marine; and in some localities microscopic shells are in great profusion.

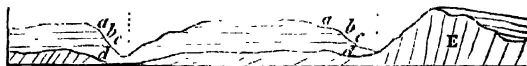
* For further details respecting the basin of the Loire, see M. Desnoyers, Ann. des Sci. Nat., tome xvi. pp. 171. 402., where full references to other authors are given.

† M. de Basterot has given a description of more than three hundred shells of Bordeaux and Dax, and figures of the greater number of them. Mém. de la Soc. d'Hist. Nat. de Paris, tome ii.

The tertiary deposits in this part of France vary much in their mineralogical character, yet admit generally of being arranged in four groups. See diagram, Fig. 115.

In some places the united thickness of these groups is considerable; but in the country between the Pyrenees and the valley of the Adour around Dax, the disturbed secondary rocks are often covered by a thin pellicle only of tertiary strata, which rests horizontally on the chalk, and does not always conceal it.

Fig. 115. Adour R. Luy R. Puy Arzet.



Tertiary strata overlying chalk in the environs of Dax.

a. Siliceous sand without shells.
b. Gravel.
c. Sand and marl with shells.
d. Blue marl with shells.
E. Chalk and volcanic tuff.

In the valleys of the Adour and Luy, sections of all the members of the tertiary series are laid open ; but the lowest blue marl, which is sometimes two hundred feet thick, is not often penetrated. On the banks of the Luy, however, to the south of Dax, the subjacent white chalk is exposed in inclined and vertical strata. In the hill called Puy Arzet the chalk, characterized by its peculiar fossils, is accompanied by beds of volcanic tuff, which are conformable to it, and which may be considered as the product of submarine eruptions which took place in the sea wherein the chalk was formed. These tuffs must once have been nearly horizontal, but, like the chalky strata, have been subjected to great subsequent derangement.

About a mile west of Orthès, in the Bas Pyrénées, the blue marl is seen to extend to the borders of the

tertiary formation, and rises to the height probably of six or seven hundred feet. In that locality many of the marine Miocene shells preserve their original colours. This marl is covered by a considerable thickness of ferruginous gravel, which seems to increase in volume near the borders of the tertiary basin on the side of the Pyrenees.

In an opposite direction, to the north of Dax, the shelly sands often pass into calcareous sandstone, in which there are merely the casts of shells, as at Carcares; and into a shelly breccia, resembling some rocks of recent origin which I have received from the coral reefs of the Bermudas.

Fresh-water limestone at Saucats.—Associated with the Miocene strata near Bordeaux, at a place called Saucats, is a compact fresh-water limestone, of slight thickness, which is perforated on the upper surface by marine shells, for the most part of extinct species. It is evident that the space must have been alternately occupied by salt and fresh water. The ground, perhaps, may have been alternately raised and depressed, or a lagoon may have been formed, in which the water became fresh; then a barrier of sand, by which the sea was excluded for a time, may have been breached, so that the salt water again obtained access.

Eocene strata in the Bordeaux basin. — The relations of some of the members of the tertiary series, in the basin of the Gironde, have of late afforded matter of controversy. A limestone, resembling the calcaire grossier of Paris, and from one hundred to two hundred feet in thickness, occurs at Pauliac and Blaye, and extends on the right bank of the Gironde, between Blaye and La Roche. It contains many species of fossils identical with those of the Paris basin. This

fact was pointed out to me by M. Deshayes before I visited Blaye in 1830; but although I recognized the mineral characters of the rock to be very different from those of the Miocene formations in the immediate neighbourhood of Bordeaux, I had not time to verify its relative position. I inferred, however, the inferiority of the Blaye limestone to the Miocene strata, from the order in which each series presented itself, as I receded from the chalk and passed to the central parts of the Bordeaux basin.

Upon leaving the white chalk with flints, in travelling from Charente by Blaye to Bordeaux, I first found myself upon overlying red clay and sand (as at Mirambeau); I then came upon the tertiary limestone above alluded to, at Blaye; and lastly, on departing still farther from the chalk, reached the strata which, at Bordeaux and Dax, contain exclusively the Miocene shells.

The occurrence both of Eocene and Miocene fossils in the same basin of the Gironde, had been cited by M. Boué as a fact which detracted from the value of zoological characters as a means of determining the chronological relations of tertiary groups. But on farther inquiry, the fact has been found to furnish additional grounds of confidence in these characters.

M. Ch. Desmoulins replied, to M. Boué's objections, that the assemblage of Eocene shells are never intermixed with those found in the "moellon," as he calls the sandy calcareous rock of the environs of Bordeaux and Dax; and M. Dufrénoy farther stated, that the hills of limestone which border the right bank of the Gironde, from Marmande as far as Blaye, present several sections wherein the Parisian (or Eocene) limestone is seen to be separated from the shelly

strata called "faluns," or "moellon," by a fresh-water formation of considerable thickness. It appears, therefore, that as the marine faluns of Touraine rest on a fresh-water formation, which overlies the marine calcaire grossier of Paris, so the marine Miocene strata of Bordeaux are separated from those of Blaye by a fresh-water deposit.*

The following diagram will express the order of position of the groups above alluded to.

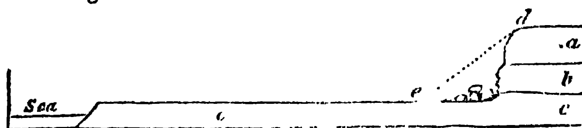
Fig. 116.



a. Red clay and sand.
b. Limestone like calcaire grossier, sometimes alternating with green marl, and containing Eocene shells.
c. Fresh-water formation, same as that of the department of Lot and Garonne.
d. Tertiary strata of the Landes, with Miocene fossils.

Inland cliff near Dax. — A few miles west from Dax, and at the distance of about twelve miles from the sea, a steep bank is seen running in a direction nearly north-east and south-west, or parallel to the contiguous coast. This steep declivity, which is about fifty feet in height, conducts us from the higher plat-

Fig. 117.



Section of Inland Cliff at Abesse, near Dax.

a. Sand of the Landes. b. Limestone. c. Clay.

* Bulletin de la Soc. Géol. de France, tome ii. p. 440.

form of the Landes to a lower plain which extends to the sea. The outline of the ground might suggest to every geologist the opinion that the bank in question was once a sea-cliff, when the whole country stood at a lower level relatively to the sea. But this can no longer be regarded as matter of conjecture. In making excavations recently for the foundation of a building at Abesse, a quantity of loose sand, which formed the slope *d e*, was removed; and a perpendicular cliff, about fifty feet in height, which had hitherto been protected from the agency of the elements, was exposed. The bottom of this cliff consists of limestone *b*, which contains shells and corals of Miocene species, and is probably a calcareous form of the division *c* (Fig. 115. p. 133.) Immediately below this limestone is the clay, *c* (probably *d*, Fig. 115., *ibid.*); and above it the usual tertiary sand, *a*, of the department of the Landes. At the base of the precipice are seen large partially rounded masses of rock, evidently detached from the stratum *b*. The face of the limestone is hollowed out and weathered into such forms as are seen in the calcareous cliffs of the adjoining coast, especially at Biaritz, near Bayonne, where the spot was pointed out to me by the proprietor of the lands of Abesse in 1830. It is evident that, when the country was at a somewhat lower level, the sea advanced along the surface of the argillaceous stratum *c*, which, from its yielding nature, favoured the waste by undermining the more solid superincumbent limestone *b*. Afterwards, when the country had been elevated, part of the sand, *a*, fell down, or was drifted by the winds, so as to form the talus, *d e*, which masked the inland cliff until it was artificially laid open to view.

The situation of this cliff is interesting, as marking

one of the pauses which intervened between the successive movements of elevation by which the marine tertiary strata of this country were upheaved to their present height, a pause which allowed time for the sea to advance and strip off the upper beds *a*, *b*, from the denuded clay *c*.

Montpellier.—The tertiary strata of Montpellier contain many of the Dax and Bordeaux species of shells, so that they are probably referrible to the Miocene epoch; but in the catalogue given by M. Marcel de Serres, many *Pliocene* species, similar to those of the Subapennine beds, are enumerated. M. de Christol mentions Mastodon angustidens, Rhinoceros leptorhinus, a Tapir, a Palæotherium, and an Anthracotherium, together with many other mammifers, besides cetacea and reptiles.*

It would be highly interesting if, upon fuller investigation, the Montpellier beds should be found to indicate a passage from the fossils of the Miocene type to those of the Older Pliocene. We may expect the discovery of such intermediate links, and I have endeavoured to provide a place for them in the classification proposed in the fifth chapter.†

Hills of Mont Ferrat and the Superga. — The late Signor Bonelli of Turin was the first who remarked that the tertiary shells found in the green sand and marl of the Superga near Turin differed, as a group, from those generally characteristic of the Subapennine beds. The same naturalist had also observed, that many of the species peculiar to the Superga were identical with those occurring near Bordeaux and

* Résumé de M. Boué, p. 128. Bull. de la Soc. Géol. de France, tom. iii.

† Vol. III. p. 397.

Dax. The strata of which the hill of the Superga is composed are inclined at an angle of more than seventy degrees, as I found when I examined the Superga in company with Mr. Murchison in 1828. They consist partly of fine sand and marl, and partly of a conglomerate composed of primary boulders, which forms a lower part of the series, and not, as represented by M. Brongniart by mistake*, an unconformable and overlying mass. The same series of beds is more largely developed in the chain of Mont Ferrat, especially in the basin of the Bormida. The high road which leads from Savona to Alessandria intersects them in its northern descent, and the formation may be well studied along this line at Carcare, Cairo, and Spinto, at all which localities fossil shells occur in a bright green sand. At Piana, a conglomerate, interstratified with this green sand, contains rounded blocks of serpentine and chlorite schist, larger than those near the summit of the Superga, some of them being not less than nine feet in diameter.

When we descend to Aqui, we find the green sand giving place to bluish marls, which also skirt the plains of the Tanaro at lower levels. These newer marls are associated with sand, and are nearly horizontal, and appear to belong to the Older Pliocene Subapennine strata.† The shells which characterize the latter abound in various parts of the country near Turin; but that region has not yet been examined with sufficient care to enable us to give exact sections to illustrate the superposition of the Miocene and Older Pliocene

* Terrains du Vicentin, p. 26.

† See section, Fig. 64. Vol. III., p. 360.

beds. It is, however, ascertained, that the highly inclined green sand, which comes immediately in contact with the primary rocks, is the oldest part of the series.*

Molasse of Switzerland. — If we cross the Alps, and pass from Piedmont to Savoy, we find there, at the northern base of the great chain, and throughout the lower country of Switzerland, a soft green sandstone much resembling some of the beds of the basin of the Bormida, above described, and associated in a similar manner with marls and conglomerate. This formation is called in Switzerland "molasse," said to be derived from "mol," "*soft*," because the stone is easily cut in the quarry. It is of vast thickness, but shells have so rarely been found in it that they do not supply sufficient data for correctly determining its age. M. Studer, in his treatise on the "molasse," enumerates some fossil shells found near Lucerne, agreeing, apparently, with those of the Subapennine hills. The correspondence in mineral character between the green sand of Piedmont and that of Switzerland can in nowise authorise us to infer identity of age, but merely to conclude that both have been derived from the degradation of similar ancient rocks.

Until the place of the "molasse" in the chronological series of tertiary formations has been more rigorously determined, the application of this provincial

* Piedmont is not wanting in able and zealous cultivators of Geology and Zoology, and it is to be hoped that MM. Pareto, Passini, Sismonda, and La Marmora will devote their attention to the relative position of the several groups of tertiary strata in their country, by instituting a comparison between their respective organic remains.

name to the tertiary groups of other countries must be very uncertain, and it will be desirable to confine it to the tertiary beds of Switzerland.

Styria, Vienna, Hungary. — Of the various groups which have hitherto been referred to the Miocene era, none are so important in thickness and geographical extent as those which are found at the eastern extremity of the Alps, in what have been termed the basins of Vienna and Styria, and which spread thence into the plains of Hungary. The collection of shells formed by M. Constant Prevost, in the neighbourhood of Vienna, and described by him in 1820 *, was alone sufficient to identify a great part of the formations of that country with the Miocene beds of the Loire, Gironde, and Piedmont. The fossil remains subsequently procured by that indefatigable observer M. Boué have served to show the still greater range of the same beds through Hungary and Transylvania.

It appears from the recently published memoirs of Professor Sedgwick and Mr. Murchison †, that the formations of Styria may be divided into groups corresponding to those adopted by M. Partsch for the Vienna beds; the basin of Styria exhibiting nearly the same phenomena as that of Vienna. These regions have evidently formed, during the Miocene period, two deep bays of the same sea, separated from each other by a great promontory connected with the central ridge of the eastern Alps.

The English geologists above mentioned describe a long succession of marine strata intervening between the Alps and the plains of Hungary, which are divi-

* Journal de Physique, Novembre, 1820.

† Geol. Trans., Second Series, vol. iii. p. 301.

sible into three natural groups, each of vast thickness, and affording a great variety of rocks. All these groups are of marine origin, and lie in nearly horizontal strata, but have throughout a slight easterly dip; so that in traversing them from west to east, we commence with the oldest, and end with the youngest beds.

At their western extremity they fill an irregular trough-shaped depression, through which the waters of the Mur, the Raab, and the Drave, make their way to the lower Danube.* Here the first group is developed, consisting of conglomerate, sandstone, and marls, some of the marls containing marine shells. Beds also of lignite occur, showing that wood was drifted down in large quantities into the sea. In parts of the series there are masses of rounded siliceous pebbles, resembling the shingle banks which are forming on some of our coasts.

The second principal group is characterized by coralline and concretionary limestone of a yellowish white colour; it is finely exposed in the escarpments of Wildon, and in the hills of Ehrenhausen, on the right bank of the Mur.† This coralline limestone is not less than 400 feet thick at Wildon, and exceeds, therefore, some of the most considerable of our secondary groups in England.‡

Beds of sandstone, sand, and shale, and calcareous marls, are associated with the above-mentioned limestone.

The third group, which occurs at a still greater distance from the mountains, is composed of sandstone

* Geol. Trans., Second Series, vol. iii. p. 382.
† Ibid., p. 385. ‡ Ibid., p. 390.

and marl, and of beds of limestone, exhibiting here and there a perfectly oolitic structure. In this system fossil shells are numerous.

In regard to the age of the formations above described, it is by no means clear that the coralline limestones of the second group are posterior in origin to all the beds of the first division; they may possibly have been formed at some distance from land, while the head of the gulf was becoming filled up with enormous deposits of gravel, sand, and mud, which may, in that quarter, have rendered the waters too turbid for the fullest development of testaceous and coralline animals.

The middle group, both in the basins of Styria and Vienna, belongs indisputably to the Miocene period; for the species of shells are the same as those of the Loire, Gironde, and other contemporary basins before noticed. Whether the lowest and uppermost systems are referrible to the same, or to distinct tertiary epochs, is the only question. We cannot doubt that the accumulation of so vast a succession of beds required an immense lapse of ages, and we should expect to find some difference in the species characterizing the different members of the series; nevertherless, all may belong to different subdivisions of the Miocene period. Professor Sedgwick and Mr. Murchison have suggested that the inferior, or first group, which comprises the strata between the Alps and the coralline limestone of Wildon, may correspond in age to the Paris basin; but the list of fossils which they have given seems rather to favour the supposition that the deposit is of the Miocene era. They mention four characteristic Miocene fossils, — Mytilus Brardii, Cerithium pictum, C. pupæforme, and C. plicatum; — and though some few

of the associated shells are common to the Paris basin, such a coincidence is no more than holds true in regard to all the European Miocene formations.

On the other hand, the third or newest system, which overlies the coralline limestone, contains fossils which do not appear to depart so widely from the Miocene type as to authorize us to separate them. They appear to agree with the tertiary strata of a great part of Hungary and Transylvania, which are referrible to the Miocene period.*

Volhynia and Podolia. — We may expect to find many other districts in Europe composed of Miocene strata; and there is already sufficient evidence that the marine deposits of the platform of Volhynia and Podolia were of this era. The fossils of that region, which is bounded by Galicia on the west, and the Ukraine on the east, and comprises parts of the basins of the Bog and the Dneister, has been investigated by Von Buch, Eichwald, and Du Bois; and the latter has given excellent plates of more than one hundred fossil shells of the country, which M. Deshayes finds to agree decidedly with the fossils of the Miocene period. †

The formation consists of sand and sandstone, clay, coarse limestone, and a white oolite, the last of which is of great extent.

Mayence. — The tertiary strata near Mayence contain in abundance the Mytilus Brardii, and several other characteristic Miocene fossils. They occupy a tract from five to twelve miles in breadth, extending along the left bank of the Rhine from Mayence to the neigh-

* See tables of shells by M. Deshayes, in Appendix I. of the octavo edition.

† Conch. Foss. du Plateau Wolhyni-Podol., par F. du Bois. Berlin, 1831.

bourhood of Manheim, and are again found to the east, north, and south-west of Frankfort. In some places they have the appearance of a fresh-water formation; but in others, as at Alzey, the shells are for the most part marine. Cerithia are in great profusion, which indicates that the sea where the deposit was formed was fed by rivers; and the great quantity of fossil land shells, chiefly of the genus Helix, confirm the same opinion. The variety in the species of shells is small, scarcely eighty having yet been discovered, as I learn from Professor Bronn, of Heidelberg, while the individuals are exceedingly numerous; a fact which accords perfectly with the idea that the formation may have originated in a gulf or sea, which, like the Baltic, was brackish in some parts and almost fresh in others. A species of Paludina, very nearly resembling the recent Littorina ulva, is found throughout this basin. These shells may be compared in size to grains of rice, and often are in such quantity as to form almost entire strata of marl and limestone. I have seen them as thick as grains of sand, in stratified masses fifteen feet thick; and Professor Bronn has observed a succession of beds thirty feet in thickness, of which they are the principal constituent.

I was unable to find any natural sections which exhibited the relations of the Mayence strata above described to the sandy beds of Eppelsheim, wherein the new genus Deinotherium, and the bones of the Mastodon avernensis and other mammifers, have been discovered. But I think it most probable that they all belong to the same era, and that the fresh-water beds of Georges Gemund, in Bavaria, as well as several other detached lacustrine groups of that country and of Wurtemburg, may be referred to the Miocene period.

At Georges Gemund, as in Touraine, we find an association of the genera Palæotherium, Mastodon, and Rhinoceros.

Osnabruch. — From the fossils which I have seen in the cabinet of Count Munster at Bayreuth, I have little doubt that strata of the Miocene period are largely developed between the mountains of the Teutobourgerwald and Wesergebirge, including the environs of Osnabruch, Münster, Astrupp, and other places.

CHAPTER XVI.

MIOCENE FORMATIONS — ALLUVIAL — FRESH-WATER — VOLCANIC.

Miocene alluviums — Auvergne — Mont Perrier — Extinct quadrupeds — Velay — Orleanais — Alluviums contemporaneous with Faluns of Touraine — Miocene fresh-water formations — Upper Val d'Arno — Extinct mammalia (p. 151.) — Coal of Cadibona — Miocene volcanic rocks — Hungary — Transylvania — Styria — Auvergne — Velay.

In the present chapter I shall offer some observations on the alluviums and fresh-water formations of the Miocene era, and shall afterwards point out the countries in Europe where the volcanic rocks of the same period may be studied.

Miocene Alluviums.

Auvergne. — The annexed drawing will explain the position of two ancient beds of alluvium, *c* and *e*, in

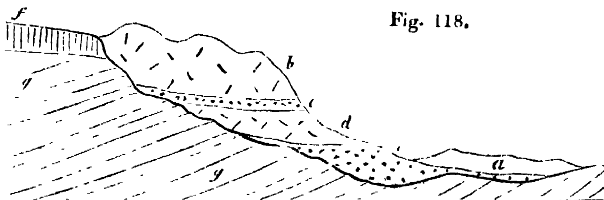


Fig. 118.

Position of the Miocene alluviums of Mont Perrier (or Boulade).

Descending series.

a. Newer alluvium. *b.* Second trachytic breccia.
c. Second Miocene alluvium with bones.
d. First trachytic breccia.
e. First Miocene alluvium with bones.
f Compact basalt. *g.* Eocene lacustrine strata.

Auvergne, in which the remains of several quadrupeds characteristic of the Miocene period have been obtained. In order to account for the situation of these beds of rounded pebbles and sand, we must suppose that after the tertiary strata *g*, covered by the basaltic lava *f*, had been disturbed and exposed to aqueous denudation, a valley was excavated, wherein the alluvium *e* was accumulated, and in which the remains of quadrupeds then inhabiting the country were buried. The trachytic breccia *d* was then superimposed; this breccia is an aggregate of shapeless and angular fragments of trachyte, cemented by volcanic tuff and pumice, resembling some of the breccias which enter into the composition of the neighbouring extinct volcano of Mont Dor in Auvergne, or those which are found on Etna. Upon this rests another alluvium, *c*, which also contains the bones of Miocene species, and this is covered by another enormous mass of tufaceous breccia. The breccias have probably resulted from the sudden rush of large bodies of water down the sides of an elevated volcano at its moments of eruption, perhaps when snow was melted by lava. Such floods occur in Iceland, sweeping away loose blocks of lava and ejections surrounding the crater, and then strewing the plains with fragments of igneous rocks, enveloped in mud or "moya." The abrupt escarpment presented by the above-described beds, *b*, *c*, *d*, *e*, towards the valley of the Couze, must have been caused by subsequent erosion, which has carried away a large portion of those masses.*

* For an account of the position and age of the volcanic breccias of Mont Perrier and Boulade, see Lyell and Murchison on the Beds of Mont Perrier, Ed. New Phil. Journ., July, 1829, p. 15.

In the alluviums *c* and *e*, MM. Croizet, Jobert, Chabriol, and Bouillet have discovered the remains of about forty species of extinct mammalia, the greater part of which are peculiar as yet to this locality; but some of them are characteristic of the Miocene period, being common to the faluns of Touraine, and associated in other localities with marine Miocene strata. Among these species may be enumerated Mastodon minor and M. arvernensis, Hippopotamus major, Rhinoceros leptorhinus, and Tapir arvernensis. The Elephas primigenius, a species common to so many tertiary periods, is also stated to accompany the rest. In some cases the remains are not sufficiently characteristic to indicate the exact species, but the following genera can be determined:—The boar, horse, ox, hyæna (two species), felis (three or four), bear (three), deer (many species), canis, otter, beaver, hare, and water-rat.*

Velay.—In Velay a somewhat similar group of mammiferous remains were found by Dr. Hibbert† in a bed of volcanic scoriæ and tuff, inclosed between two beds of basaltic lava, at Saint Privat d'Allier. Some of the bones were found adhering to the slaggy lava. Among the animals were Rhinoceros leptorhinus, Hyæna spelæa, and another species allied to the spotted hyæna of the Cape, together with four undetermined species of deer.‡

At Cussac and Solilhac, one league from Puy en

* Recherches sur les Oss. Foss. du Dépt. du Puy de Dome, 4to. 1828. Essai Géol. et Minéral. sur les Environs d'Issoire, Dépt. du Puy de Dome, folio, 1827.

† Edin. Journ. of Sci., No. iv. New Series, p. 276.

‡ Figures of some of these remains are given by M. Bertrand de Doue, Ann. de la Soc. d'Agricult. de Puy, 1828.

Velay, M. Robert discovered, in an ancient alluvium covered with lava, the remains of Elephas primigenius, Rhinoceros leptorhinus, Tapir arvernensis, horse (two species), deer (seven species), ox (two species), and an antelope.

Orleanais.—In the Orleanais, at Avaray, Chevilly, les Aides, and les Barres, fossil land quadrupeds have been found associated with fluviatile shells and reptiles, identical with those found in the marine faluns of Touraine.* These are supposed with great probability, by M. Desnoyers, to mark the passage of streams which flowed towards the sea in which the faluns were deposited. They bear the same relation to the Miocene strata of Touraine, as the bones of elephants and other extinct animals, in the ancient gravel and silt of England, probably bear to the crag.

Miocene Fresh-water Formations.

Upper Val d'Arno.—There are a great number of isolated tertiary formations, of fresh-water origin, resting on primary and secondary rocks in different parts of Europe, in the same manner as we now find small lakes scattered over our continents and islands, wherein deposits are forming, quite detached from all contemporary marine strata. To determine the age of such groups, with reference to the great chronological series established for the marine strata, must often be a matter of difficulty, since we cannot always enjoy an opportunity of studying a locality where the fresh-water species are intermixed with marine shells, or where they occur in beds alternating with marine strata.

* MM. Desnoyers and Lockart, Bulletin de la Soc. Géol., tom. ii. p. 336.

The deposit of the Upper Val d'Arno before alluded to (p. 71.), was evidently formed in an ancient lake; but, although the fossil testaceous and mammiferous remains preserved therein are very numerous, it is scarcely possible, at present, to decide with certainty the precise era to which they belong. I collected six species of lacustrine shells, in an excellent state of preservation, from this basin, belonging to the genera Anodon, Paludina, and Neritina; but M. Deshayes was unable to identify any one of them with any recent or fossil species known to him. If the beds belonged to the Older Pliocene formations, we might expect that several of the fossils would agree specifically with living testacea; and I am therefore disposed to believe that they belong to an older epoch. If we consider the terrestrial mammalia of the same beds, we immediately perceive that they cannot be assimilated to the Eocene type, as exhibited in the Paris basin, or in Auvergne and Velay: but some of them agree with Miocene species. Mr. Pentland has obligingly sent me the following list of the fossil mammifers of the upper Val d'Arno which are in the museums of Paris.——*Feræ*—Ursus cultridens, Viverra Valdarnensis, Canis lupus (?), and another of the size of the common fox. Hyæna radiata, H. fossilis. Felis (a new species, of the size of the panther). *Rodentia* — Histrix, nearly allied to dorsalis, Castor. *Pachydermata* — Elephas Italicus, Mastodon angustidens, M. Taperoides, Tapir ——, Equus ——, Sus scrofa, Rhinoceros leptorhinus, Hippopotamus major, fossilis. *Ruminantia* —Cervus megaceros (?), C. Valdarnensis, C. —— (new species), Bos, bubalo affinis, B. urus and B. taurus.

Cuvier also mentions the remains of a species of

lophiodon as occurring among the bones in the Upper Val d'Arno.* The elephant of this place has been called by Nesti † *meridionalis*, and is considered by him as distinct from the Siberian fossil species *E. primigenius*, with which, however, some eminent comparative anatomists regard it as identical. The skeletons of the hippopotamus are exceedingly abundant; no less than forty had been procured when I visited Florence in 1828. Remains of the elephant, stag, ox, and horse, are also extremely numerous. In winter the superficial degradation of the soil is so rapid, that bones which the year before were buried are seen to project from the surface of the soil, and are described by the peasants as growing. In this manner the tips of the horns of stags, or of the tusks of hippopotamuses, often appear on the surface, and thus lead to the discovery of an entire head or skeleton.

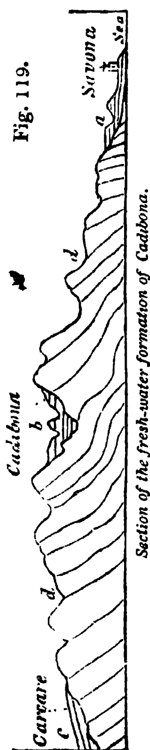


Fig. 119.

Section of the fresh-water formation of Cadibona.

a. Blue marl and yellow sand (Older Pliocene). *b.* Sand, shale, and coal of Cadibona (Miocene?). *c.* Green sand, &c. of the Bormida (Miocene). *d.* Chloritic and Micaceous schist, serpentine, &c.

Cadibona. — Another example of an isolated lacustrine deposit, belonging possibly to the Miocene period, is that which occurs at Cadi-

* Oss. Foss., vol. v. p. 504.

† Lettere sopra alcune Ossa Fossili del Val d'Arno, &c. Pisa, 1825.

bona, between Savona and Carcare, a place which I visited in August, 1828, in company with Mr. Murchison. Its position is described in the annexed section, which does not, however, pretend to accuracy in regard to the relative heights of the different rocks, or the distances of the places from each other. The lacustrine strata are composed of gravel, grit, and micaceous sandstone, of such materials as were derivable from the surrounding primary rocks; and so great is the thickness of this mass, that some valleys intersect it to the depth of seven or eight hundred feet without penetrating to the subjacent formations. In one part of the series, carbonaceous shales occur, and several seams of coal from two to six feet in thickness; but no impressions of plants of which the species could be determined, and no shells have been discovered. Many entire jaws and other bones of an extinct mammifer, called by Cuvier Anthracotherium, have been found in the coal-beds, the bone being itself changed into a kind of coal; but as this species has not as yet occurred elsewhere in association with organic remains of known date, it affords us no aid when we attempt to assign a place to the lignites of Cadibona.

Miocene Volcanic Rocks.

Hungary.—M. Beudant, in his elaborate work on Hungary, describes five distinct groups of volcanic rocks, which, although nowhere of great extent, form striking features in the physical geography of that country, rising as they do abruptly from extensive plains composed of tertiary strata. They may have constituted islands in the ancient sea, as Santorin and Milo now do in the Grecian Archipelago; and M. Beu-

dant has remarked that the mineral products of the last-mentioned islands resemble remarkably those of the Hungarian extinct volcanos, where many of the same minerals, as opal, calcedony, resinous silex (*silex resinite*), pearlite, obsidian, and pitchstone abound.

The Hungarian lavas are chiefly felspathic, consisting of different varieties of trachyte; many are cellular, and used as millstones; some so porous and even scoriform as to resemble those which have issued in the open air. Pumice occurs in great quantity; and there are conglomerates, or rather breccias, wherein fragments of trachyte are bound together by pumiceous tuff, or sometimes by silex.

It is probable that these rocks were permeated by the waters of hot springs, impregnated, like the Geysers, with silica; or, in some instances, perhaps, by aqueous vapours, which, like those of Lancerote, may have precipitated hydrate of silica.*

By the influence of such springs or vapours the trunks and branches of trees washed down during floods, and buried in tuffs on the flanks of the mountains, may have become silicified. It is scarcely possible, says M. Beudant, to dig into any of the pumiceous deposits of these mountains without meeting with opalized wood, and sometimes entire silicified trunks of trees of great size and weight.

It appears from the species of shells collected principally by M. Boué, and examined by M. Deshayes, that the fossil remains imbedded in the volcanic tuffs, and in strata alternating with them in Hungary, are of the Miocene type, and not identical, as was formerly supposed, with the fossils of the Paris basin.

* See Vol. II. p. 195.

Transylvania.—The igneous rocks of the eastern part of Transylvania, described by M. Boué, are probably of the same age. They cover a considerable area, and bear a close resemblance to the Hungarian lavas, being chiefly trachytic. Several large craters, containing shallow lakes, like the Maars of the Eifel, are met with in some regions; and a rent in the trachytic mountains of Budoshagy exhales hot sulphureous vapours, which convert the trachyte into alum-stone, a change which that rock has undergone at remote periods in several parts of Hungary.

Styria.—Many of the volcanic groups of this country bear a similar relation to the Styrian tertiary deposits, as do the Hungarian rocks to the marine strata of that country. The shells are found imbedded in the volcanic tuffs in such a manner as to show that they lived in the sea when the volcanic eruptions were in progress, as many of the Val di Noto lavas in Sicily, before described, were shown to be contemporaneous with Newer Pliocene strata.*

Auvergne—Velay.—I believe that part of the volcanic eruptions of Auvergne took place during the Miocene period; those, for example, which cover, or are interstratified with, the alluviums mentioned in this chapter, and some of the ancient basaltic cappings of hills in Auvergne, which repose on gravel characterized by similar organic remains. A part also of the igneous rocks of Velay must belong to this epoch; but these will be again referred to when I treat more fully of the volcanic rocks of Central France, the older part of which are referrible to the Eocene period.

* Sedgwick and Murchison, Geol. Trans., Second Series, vol. iii. p. 400. Daubeny, Extinct Volcanos, p. 92.

CHAPTER XVII.

EOCENE FRESH-WATER FORMATIONS.

Eocene period — Fresh-water formations — Central France — Map — Limagne d'Auvergne — Sandstone and conglomerate — Tertiary red marl and red sandstone — Green and white foliated marls (p. 162.) — Indusial limestone — Gypseous marls — Travertin — Fresh-water formation of Puy en Velay (p. 170.) — Of Cantal — Resemblance of Aurillac limestone and flints to our upper chalk — Concluding remarks.

We have now traced back the history of the European formations to that period when the seas and lakes were inhabited by testacea, of which a few only belonged to species now existing, a period which I have designated *Eocene*, as indicating the *dawn* of the present state of the animate creation. But although a small number only of the living species of animals were then in being, there are ample grounds for inferring that all the great classes of the animal kingdom, such as they now exist, were then fully represented. In regard to the testacea, indeed, it is no longer a matter of inference; for more than 1200 species of this class have been obtained from that small number of detached Eocene deposits which have hitherto been examined in Europe.

The celebrated Paris basin, the position of which was pointed out in the former part of this book (see wood-cut, Vol. III. p. 354.), first presents itself, and

seems to claim our chief attention when we examine the phenomena of this era. But in order the more easily to explain the peculiar nature and origin of that group, it will be desirable, first, to give a brief sketch of certain deposits of Central France, which afford many interesting points of analogy to that of Paris, both in organic remains and mineral composition, and where the original circumstances under which the strata were accumulated may more easily be discerned.

Auvergne.—The deposits alluded to, which I examined in the summer of 1828, in company with Mr. Murchison, are those of the lacustrine basins of Auvergne, Cantal, and Velay, and their sites may be seen in the annexed Map. They appear to be the monuments of ancient lakes, which may have resembled in geographical distribution some of those now existing in Switzerland, and may like them have occupied the depressions in a mountainous country, and have been each fed by one or more rivers and torrents. The country where they occur is almost entirely composed of granite and different varieties of granitic schist, with here and there a few patches of secondary strata much dislocated, and which have probably suffered great denudation. There are also some vast piles of volcanic matter (see the Map), the greater part of which is newer than the fresh-water strata, and is sometimes seen to rest upon them, whilst a small part has evidently been of contemporaneous origin. Of these igneous rocks I shall treat more particularly in the nineteenth chapter, and shall now speak only of the lacustrine beds.

The most northern of the fresh-water groups is situated in the valley-plain of the Allier, which lies within

Fig 120.

PARIS BASIN

Freshwater

Volcanic

Sancerre

Loire R.

Nevers

47

Moulins

Loire R.

Montlucon

GRANITIC PLATFORM.

AUVERGNE.

FOREZ.

Gannat

Vichy

46

Monts Domes

Clermont

M^t d'Or

Montbrison

Loire R.

VELAY

Le Puy

Mauriac

Murat

Cantal

Allier R.

Pradelles

the department of the Puy de Dome, being the tract which went formerly by the name of the Limagne d'Auvergne. It is inclosed by two parallel primitive ranges,—that of the Forèz, which divides the waters of the Loire and Allier, on the east; and that of the Monts Domes, which separates the Allier from the Sioule, on the west.* The average breadth of this tract is about twenty miles; and it is for the most part composed of nearly horizontal strata of sand, sandstone, calcareous marl, clay, and limestone, none of which observe a fixed and invariable order of superposition. The ancient borders of the lake wherein the fresh-water strata were accumulated, may generally be traced with precision, the granite and other ancient rocks rising up boldly from the level country. The precise junction, however, of the lacustrine and granitic beds is rarely seen, as a small valley usually intervenes between them. The fresh-water strata may sometimes be seen to retain their horizontality within a very slight distance of the border-rocks, while in some places they are inclined, and in a few instances vertical. The principal divisions into which the lacustrine series may be separated are the following:—1st, Sandstone, grit, and conglomerate, including red marl and red sandstone. 2dly, Green and white foliated marls. 3dly, Limestone or travertin, oolite. 4thly, Gypseous marls.

1. *a. Sandstone and conglomerate.*—Strata of sand and gravel, sometimes bound together into a solid rock, are found in great abundance around the confines of the lacustrine basin, containing, in different places, pebbles of all the ancient rocks of the adjoining ele-

* Scrope, Geology of Central France, p. 15.

vated country; namely, granite, gneiss, mica-schist, clay-slate, porphyry, and others. But the arenaceous strata do not form one continuous band around the margin of the basin, being rather disposed like the independent deltas which grow at the mouths of torrents along the borders of existing lakes.*

At Chamalieres, near Clermont, we have an example of one of these littoral groups of local extent, where the pebbly beds slope away from the granite as if they had formed a talus beneath the waters of the lake near the steep shore. A section of about fifty feet in vertical height has been laid open by a torrent, and the pebbles are seen to consist throughout of rounded and angular fragments of granite, quartz, primary slate, and red sandstone; but without any intermixture of those volcanic rocks which now abound in the neighbourhood. Partial layers of lignite and pieces of wood are found in these beds, but no shells; a fact which probably indicates that testacea could not live where the turbid waters of a stream were frequently hurrying down uprooted trees, together with sand and pebbles, or, that if they existed, they were triturated by the transported rocks.

There are other localities on the margin of the basin where quartzose grits are found, composed of white sand bound together by a siliceous cement.

Occasionally, when the grits rest on granite, as at Chamalieres before mentioned, and many other places, the separate crystals of quartz, mica, and felspar, of the disintegrated granite, are bound together again by the silex, so that the granite seems regenerated in a new and even more solid form; and thus so gradual a

* See book ii. chap. v.

passage may easily be traced between a crystalline rock and one of mechanical origin, that we can scarcely distinguish where one ends and the other begins.

In the Puy de Jussat, and the neighbouring hill of La Roche, are white quartzose grits, cemented by calcareous matter, which is sometimes so abundant as to form imbedded nodules. These sometimes constitute spheroidal concretions six feet in diameter, and pass into beds of solid limestone resembling the Italian travertins, or the deposits of mineral springs.

In the hills above mentioned, we have the advantage of seeing a section continuously exposed for about seven hundred feet in thickness. At the bottom are foliated marls, white and green, about four hundred feet thick; and above, resting on the marls, are the quartzose grits before mentioned, with the associated travertins. This section is close to the confines of the basin; so that the lake must here have been filled up near the shore with fine mud, before the coarse superincumbent sand was introduced. There are other cases where sand is seen below the marl.

1. *b. Red marl and sandstone.*—But the most remarkable of the arenaceous groups is one of red sandstone and red marl, which are identical in all their characters with the secondary *new red sandstone* and marl of England. In these secondary rocks, the red ground is sometimes variegated with light greenish spots, and the same may be seen in the tertiary formation of fresh-water origin at Coudes, on the Allier. The marls are sometimes of a purplish-red colour, as at Champheix, and are accompanied by a reddish limestone like the well-known "cornstone," which is associated with the old red sandstone of English geologists. The red sandstone and marl of Auvergne have evidently been

derived from the degradation of gneiss and mica-schist, which are seen *in situ* on the adjoining hills, decomposing into a soil very similar to the tertiary red sand and marl. We also find pebbles of gneiss, mica-schist, and quartz, in the coarser sandstones of this group, clearly pointing to the parent rocks from which the sand and marl were derived. The red beds, although destitute themselves of organic remains, pass upwards into strata containing Eocene fossils, and are certainly an integral part of the lacustrine formation.

2. *Green and white foliated marls.*—A great portion of what we term clay in ordinary language consists of the same materials as sand, but the component parts are in a finer state of subdivision. The same primary rocks, therefore, of Auvergne which, by the partial degradation of their harder parts, gave rise to the quartzose grits and conglomerates before mentioned, would, by the reduction of the same materials into powder, and by the decomposition of their felspar, mica, and hornblende, produce aluminous clay; and, if a sufficient quantity of carbonate of lime was present, calcareous marl. This fine sediment would naturally be carried out to a greater distance from the shore, as are the various finer marls now deposited in Lake Superior.* And, as in the American lake, shingle and sand are annually amassed near the northern shores, so in Auvergne the grits and conglomerates before mentioned were evidently formed near the borders.

The entire thickness of these marls is unknown; but it certainly exceeds, in some places, seven hundred feet. They are for the most part either light-green or white, and usually calcareous. They are thinly fol-

* See Vol. I. p. 340.

iated,—a character which frequently arises from the innumerable thin plates or scales of that small animal called *Cypris;* a genus which comprises several species, of which some are recent, and may be seen swimming swiftly through the waters of our stagnant pools and ditches. The antennæ at the end of which are fine

Fig. 121.

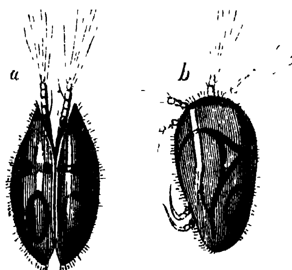
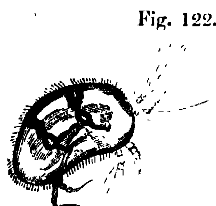


Fig. 122.



Cypris unifasciata, a living species, greatly magnified.

Cypris vidua, a living species greatly magnified.*

a. Upper part. *b*. Side view of the same.

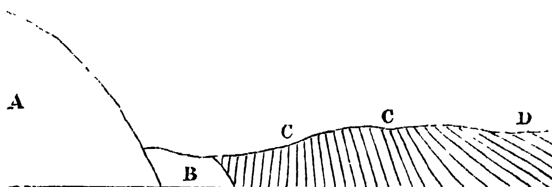
pencils of hair, are the principal organs for swimming, and are moved with great rapidity. This animal resides within two small valves not unlike those of a bivalve shell, and moults its integuments annually, which the conchiferous molluscs do not. This circumstance may partly explain the countless myriads of the shells of cypris which were shed in the Eocene lakes, so as to give rise to divisions in the marl as thin as paper, and that too in stratified masses several hundred feet thick. A more convincing proof of the tranquillity and clearness of the waters, and of the slow and gradual process by which the lake was filled up with fine mud, cannot be desired. But we may

* See Desmarest's Crustacea, plate 55.

easily suppose that, while this fine sediment was thrown down in the deep and central parts of the basin, gravel, sand, and rocky fragments were hurried into the lake near the shore, and formed the group described in the preceding section.

Not far from Clermont, the green marls, containing the cypris in abundance, approach to within a few yards

Fig. 123.



Vertical strata of marl near Clermont.

A. Granite. B. Space of sixty feet, in which no section is seen. C. Green marl, vertical and inclined. D. White marl.

of the granite which forms the borders of the basin. The annexed section occurs at Champradelle, in a small ravine north of La petite Baraque, and above the bridge.

The occurrence of these marls so near the ancient margin may be explained by considering that, at the bottom of the ancient lake, no coarse ingredients were deposited in spaces intermediate between the points where rivers and torrents entered, but finer mud only was drifted there by currents. The *verticality* of some of the beds in the above section bears testimony to considerable local disturbance subsequent to the deposition of the marls; but such inclined and vertical strata are very rare.

3. *Limestone, travertin, oolite.*—Both the preceding members of the lacustrine deposit, the marls and grits,

pass occasionally into limestone. Sometimes only concretionary nodules abound in them; but these, where there is an increase in the quantity of calcareous matter, unite, as already noticed (p. 161.), into regular beds.

On each side of the basin of the Limagne, both on the west at Gannat, and on the east at Vichy, a white oolitic limestone is quarried. At Vichy, the oolite resembles our Bath stone in appearance and beauty, and, like it, is soft when first taken from the quarry, but soon hardens on exposure to the air. At Gannat, the stone contains land-shells and bones of quadrupeds, resembling those of the Paris gypsum. In several places in the neighbourhood of Gannat, at Marculot among others, this stone is divided by layers of clay.

At Chadrat, in the hill of La Serre, the limestone is pisolitic, and in this and other respects resembles the travertin of Tivoli. It presents the same combination of a radiated and concentric structure, and the coats of the different spheroids have the same undulating surface.*

Indusial limestone. — There is another remarkable form of fresh-water limestone in Auvergne, called "indusial," from the cases, or *indusiæ*, of the larvæ of Phryganea, great heaps of which have been encrusted, as they lay, by carbonate of lime, and formed into a hard travertin. Several beds of this rock, either in continuous masses, or in concretionary nodules, are seen superimposed one upon another, with layers of marl interposed. We may often observe in our ponds some of the living species of this kind of insect, covered with

* See Fig. 9. Vol. I. p. 319.

small fresh-water shells, which they have the power of fixing to the outside of their tubular cases, in order, probably, to give them weight and strength.

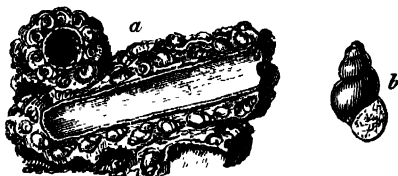
Fig. 124.



*Larva of recent Phryganea.**

The individual figured in the annexed cut, which belongs to a species very abundant in England, has happened to cover its case with shells of a small Planorbis. In the same manner, a large species which swarmed in the Eocene lakes of Auvergne was accustomed to attach to its dwelling the shells of a small spiral univalve of the genus *Paludina.* A hundred of these minute shells are sometimes seen arranged around one tube, part of the central cavity of which is often empty, the rest being filled up with thin concentric layers of travertin. The cases have been thrown together confusedly, and often lie, as in Fig. 125., at right angles one to the other. When we consider that ten or twelve tubes are packed within the compass of a cubic inch, and that some single strata of this

Fig. 125.



a. Indusial limestone of Auvergne.
b. Fossil Paludina magnified.

* I believe that the British specimen here figured is P. rhombica, Linn.

limestone are six feet thick, and may be traced over a considerable area, we may form some idea of the countless number of insects and mollusca which contributed their integuments and shells to compose this singularly constructed rock. It is unnecessary to suppose that the Phryganeæ lived on the spots where their cases are now found; they may have multiplied in the shallows near the margin of the lake, or in the streams by which it was fed, and their buoyant cases may have been drifted by a current far into the deep water.*

The calcareous strata of the Limagne, like the other members of this lacustrine formation, are for the most part horizontal, or inclined at a very slight angle, but instances of local dislocation are sometimes observable. At the town of Vichy, for example, in an ancient quarry behind the convent of Celestines, the strata dip at an angle of between thirty and forty degrees; and near the hot spring at the same place, the beds of limestone are seen, in one part of the section, inclined at an angle of eighty degrees, and in another vertical.

4. *Gypseous marls.* — More than fifty feet of thinly laminated gypseous marls, exactly resembling those in the hill of Montmartre, at Paris, are worked for gypsum at St. Romain, on the right bank of the Allier. They rest on a series of green cypriferous marls which alternate with grit, the united thickness of this inferior group being seen, in a vertical section on the banks of the river, to exceed 250 feet.

General arrangement and origin of the fresh-water formations of Auvergne. — The relations of the different groups above described cannot be learnt by the study

* For remarks on the floating of empty land shells by rivers, see p. 47., and Vol. III. p. 382.

of any one section, and the geologist who sets out with the expectation of finding a fixed order of succession may perhaps complain that the different parts of the basin give contradictory results. The arenaceous division (1. p. 159.), the marls (2. p. 162.), and the limestone (3. p. 164.), may all be seen in some places to alternate with each other; yet it can by no means be affirmed that there is no order of arrangement. The sands, sandstone, and conglomerate, constitute in general a littoral group; the foliated white and green marls, a contemporaneous central deposit; and the limestone is for the most part subordinate to the newer portions of both. The uppermost marls and sands are more calcareous than the lower; and we never meet with calcareous rocks covered by a considerable thickness of quartzose sand or green marl. From the resemblance of the Eocene limestones of Auvergne to the Italian travertins, we may conclude that they were derived from the waters of mineral springs, — such springs as now exist in Auvergne, and which, rising up through the granite, precipitate travertin. They are sometimes thermal, but this character is by no means constant.

It seems that, when the ancient lake of the Limagne first began to be filled with sediment, no volcanic action had yet produced lava and scoriæ on any part of the surface of Auvergne. No pebbles, therefore, of lava were transported into the lake, — no fragments of volcanic rocks imbedded in the conglomerate. But at a later period, when a considerable thickness of sandstone and marl had accumulated, eruptions broke out, and lava and tuff were deposited, at some spots, alternately with the lacustrine strata. Proofs of this will be given in the 19th chapter. It is

not improbable that cold and thermal springs, holding different mineral ingredients in solution, became more numerous during the successive convulsions attending this development of volcanic agency, and thus deposits of carbonate and sulphate of lime, silex, and other minerals, were produced. Hence these minerals predominate in the uppermost strata. The subterranean movements may then have continued until they altered the relative levels of the country and caused the waters of the lakes to be drained off, and the farther accumulation of regular fresh-water strata to cease. The occurrence of these convulsions anterior to the Miocene epoch, and their continuance during a succession of after-ages, may explain why no fresh-water formations more recent than the Eocene are now found in this country.

We may easily conceive a similar series of events to give rise to analogous results in any modern basin, such as that of Lake Superior, for example, where numerous rivers and torrents are carrying down the detritus of a chain of mountains into the lake. The transported materials must be arranged according to their size and weight, the coarser near the shore, the finer at a greater distance from land; but in the gravelly and sandy beds of Lake Superior no pebbles of modern volcanic rocks can be included, since there are none of these at present in the district. If igneous action should break out in that country and produce lava, scoriæ, and thermal springs, the deposition of gravel, sand, and marl might still continue as before; but in addition, there would then be an intermixture of volcanic gravel and tuff, and of rocks precipitated from the waters of mineral springs.

Although the fresh-water strata of the Limagne ap-

proach generally to a horizontal position, the proofs of local disturbance are sufficiently numerous and violent to allow us to suppose great changes of level since the Eocene period. We are unable to assign a northern barrier to the ancient lake, although we can still trace its limits to the east, west, and south, where they were formed of bold granitic eminences. But we need not be surprised at our inability to restore the physical geography of the country after so great a series of volcanic eruptions; for it is by no means improbable that one part of it may have been moved upwards bodily, while others remained at rest, or even suffered a movement of depression.

Puy en Velay.—In the department of the Haute Loire, a fresh-water formation, very analogous to that of Auvergne, is situated in the basin of the Loire, and is exposed in the valley in which stands the town of Le Puy. Since the deposition of the lacustrine strata, there have been so many volcanic eruptions in this country, and such immense quantities of lava and scoriæ have been poured out upon the surface, that the aqueous rocks are almost buried and concealed. But we are indebted to the researches of M. Bertrand de Doue, for having distinctly ascertained the succession of strata, and I have myself had opportunities of verifying his observations during a visit to Le Puy.

In this basin we find, as in Auvergne, two great divisions, consisting of grits and marls; the former composed of quartzose grit, in some places resembling granite, and of reddish and mottled sands and conglomerates. All these were evidently derived from the degradation of granitic rocks, and are very like the arenaceous group of the Limagne before described. They are almost confined to the borders of the basin,

and were evidently a littoral deposit. The other member of the formation, the *marls*, are more or less calcareous, and are associated with limestone and gypsum, which last exactly resembles that of Paris, and is worked for agricultural uses.

The analogy in the mineral character of the Velay and Paris basins is rendered more complete by the presence in both of silex in regular beds. In the limestone I found gyrogonites, or seeds of the Chara, of the same species as those most common in the Paris basin; and M. Bertrand de Doue has discovered the bones of several mammiferous animals of the same genera as those which characterize the basins of Auvergne and Paris.* The species of shells also of this formation are the same as those of Eocene formations in other parts of France.

The sand and conglomerate of the fresh-water basin of Velay are entirely free from volcanic pebbles, agreeing in this respect with the analogous group of the Limagne; but the fact is the more striking in Velay, because the masses of trachyte, clinkstone, and other igneous rocks now abounding in that country, have an aspect of very high antiquity, and constitute a most prominent feature in the geological structure of the district. Yet the non-intermixture of volcanic products with the lacustrine sediment, is just what we should expect when we have ascertained that the imbedded organic remains of those strata are Eocene; whereas the lavas belong in part, if not entirely, to the Miocene period.†

Cantal. — Near Aurillac, in Cantal, another series of fresh-water strata occurs, which resembles, in mi-

* Descrip. Géognos. des Env. du Puy en Velay, 1823.

† See p. 149., and chap. xix.

neral character and organic remains, those of Auvergne and Velay already described. The leading feature of this group, as distinguished from the two former, is the immense abundance of silex associated with the calcareous marls and limestone, which last constitute, like the limestone of Auvergne, an upper member of the fresh-water series.

The formations of the Cantal may be divided into two groups, the lower composed of gravel, sand, and clay, such as might have been derived from the wearing down and decomposition of the granitic schists of the surrounding country; the upper system consisting of siliceous and calcareous marls, contains subordinately gypsum, silex, and limestone — deposits such as the waters of springs charged with carbonate and sulphate of lime, and with silica, may have produced.

Fresh-water limestone and flints resembling chalk. — To the English geologist, the most interesting feature in the Cantal is the resemblance of the fresh-water limestone, and its accompanying flint, to our upper chalk; a resemblance which (like that of the red sandstone of Auvergne to our secondary "new red") is the more important, as being calculated to put the student upon his guard against relying too implicitly on lithological characters as tests of the relative ages of rocks. When we approach Aurillac from the west, we pass over great heathy plains, where the sterile mica-schist is barely covered with vegetation. Near Ytrac, and between La Capelle and Viscamp, we find the surface strewed over with loose broken flints, some of them black in the interior, but with a white external coating; others stained with tints of yellow and red, and in appearance precisely like the flint gravel of our chalk districts. When heaps of this gravel have thus

announced our approach to a new formation, we arrive at length at the escarpment of the lacustrine beds. At the bottom of the hill which rises before us, we see strata of clay and sand resting on mica-schist; and above, in the quarries of Belbet, Leybros, and Bruel, a white limestone, in horizontal strata, the surface of which has been hollowed out into irregular furrows, since filled up with broken flint, marl, and dark vegetable mould. In these cavities we recognize an exact counterpart to those which are so numerous on the furrowed surface of our own white chalk. Advancing from these quarries, along a road made of the white limestone, which reflects as glaring a light in the sun, as do our roads composed of chalk, we reach, at length, in the neighbourhood of Aurillac, hills of limestone and calcareous marl, in horizontal strata, separated in some places by regular layers of flint in nodules, the coating of each nodule being of an opaque white colour, like the exterior of the flinty nodules of our chalk. This hard white substance has been ascertained in England to consist, in some instances, wholly of siliceous matter, and sometimes to contain a small admixture of carbonate of lime*, and the analysis of the similar rocks in the Cantal would probably give the same results. The Aurillac flints have precisely the appearance of having separated from their matrix after the siliceous and calcareous matter had been blended together. The calcareous marl sometimes occupies small sinuous cavities in the flint; and the siliceous nodule, when detached, is often as irregular in form as those found in our chalk.

By what means, then, can the geologist at once

* Phillips, Geol. Trans. First Series vol. v. p. 22.—Outlines of Geology, p. 95.

decide that the limestone and silex of Aurillac are referrible to an epoch entirely distinct from that of the English chalk? It is not by reference to position; for we can merely say of the lacustrine beds, as we should have been able to declare of the true chalk had it been present, that they overlie the granitic rocks of this part of France. It is from the organic remains only that we are able to pronounce the formation to belong to the Eocene tertiary period. Instead of the marine Alcyonia of our cretaceous system, the silicified seed-vessels of the Chara, a plant which grows at the bottom of lakes, abound in the flints of Aurillac, both in those which are *in situ* and those forming the gravel. Instead of the Echini and marine testacea of the chalk, we find in these marls and limestones the shells of the Planorbis, and other lacustrine testacea, all of them, like the gyrogonites, agreeing specifically with species of the Eocene type.

Proofs of the gradual deposition of marl. — Some sections of the foliated marls in the valley of the Cer, near Aurillac, attest, in the most unequivocal manner, the extreme slowness with which the materials of the lacustrine series were amassed. In the hill of Barrat, for example, we find an assemblage of calcareous and siliceous marls, in which, for a depth of at least sixty feet, the layers are so thin that thirty are sometimes contained in the thickness of an inch; and when they are separated we see preserved in every one of them the flattened stems of Charæ, or other plants, or sometimes myriads of small *paludinæ* and other fresh-water shells. These minute foliations of the marl resemble precisely some of the recent laminated beds of the Scotch marl lakes, and may be compared to the pages of a book, each containing a history of a certain period

of the past. The different layers may be grouped together in beds from a foot to a foot and a half in thickness, which are distinguished by differences of composition and colour, the tints being white, green, and brown. Occasionally there is a parting layer of pure flint, or of black carbonaceous vegetable matter, about an inch thick, or of white pulverulent marl. We find several hills in the neighbourhood of Aurillac composed of such materials for the height of more than 200 feet from their base, the whole sometimes covered by rocky currents of trachytic or basaltic lava.*

Thus wonderfully minute are the separate parts of which some of the most massive geological monuments are made up! When we desire to classify, it is necessary to contemplate entire groups of strata in the aggregate; but if we wish to understand the mode of their formation, and to explain their origin, we must think only of the minute subdivisions of which each mass is composed. We must bear in mind how many thin leaf-like seams of matter, each containing the remains of myriads of testacea and plants, frequently enter into the composition of a single stratum, and how vast a succession of these strata unite to form a single group! We must remember also, that volcanos like the Plomb du Cantal, which rises in the immediate neighbourhood of Aurillac, are themselves equally the result of successive accumulation, consisting of reiterated flows of lava and showers of scoriæ; and I have shown, when treating of the high antiquity of Etna, how many dis-

* Lyell and Murchison, sur les Dépôts Lacust. Tertiaires du Cantal, &c. Ann. des Sci. Nat., Oct. 1829.

tinct lava-currents and heaps of ejected substances are required to make up one of the numerous conical envelopes whereof a volcano is composed. — Lastly, we must not forget that continents and mountain-chains, colossal as are their dimensions, are nothing more than an assemblage of many such igneous and aqueous groups, formed in succession during an indefinite lapse of ages, and superimposed upon each other.

CHAPTER XVIII.

EOCENE FORMATIONS — PARIS BASIN.

Marine Eocene strata — Paris basin how far analogous to deposits of Central France — Connexion of Auvergne and Paris basins — Groups in Paris basin — Observations of M. C. Prevost — Contemporaneous marine and fresh-water strata — Abundance of Cerithia (p. 182.) — Upper marine formation — All the Parisian groups Eocene — Microscopic shells (p. 189.) — Bones of quadrupeds in gypsum — Strata with and without organic remains alternating — Extent of our knowledge of the physical geography, fauna, and flora of the Eocene period — Concluding remarks.

The geologist who has studied the lacustrine formations described in the last chapter cannot enter the tract usually termed "the Paris Basin" without immediately recognizing a great variety of rocks with which his eye has already become familiar. The green and white marls of Auvergne, Cantal, and Velay, again present themselves, together with limestones and quartzose grits, siliceous and gypseous marls, nodules and layers of flint, and saccharoid gypsum; lastly, in addition to all this identity of mineral character, he finds an assemblage of the same species of fossil animals and plants.

When we consider the geographical proximity of the two districts, we are the more prepared to ascribe this correspondence in the mineral composition of these groups to a combination of similar circumstances

at the same era. From the map (Fig. 120. p. 158.) in the last chapter, it will be seen that the united waters of the Allier and Loire, after descending from the valleys occupied by the fresh-water formations of Central France, flow on till they reach the southern extremity of what is called the Paris basin. M. Omalius d'Halloy long ago suggested the very natural idea that there existed formerly a chain of lakes, reaching from the highest part of the central mountain-group of France, and terminating in the basin of Paris, which he supposes was at that time an arm of the sea.

Notwithstanding the great changes which the physical geography of this part of France must since have undergone, we may easily conceive that many of the principal features in the configuration of the country may have remained unchanged, or but slightly modified. Hills of volcanic matter have indeed been formed since the Eocene formations were accumulated, and the levels of large tracts have been altered in relation to the sea; lakes have been drained, and a gulf of the sea turned into dry land, but many of the reciprocal relations of the different parts of the surface may still remain the same. The waters which flowed from the granitic heights into the Eocene lakes may now descend in the same manner through valleys once the basins of those lakes. Let us, for illustration, suppose the great Canadian lakes, and the gulf into which their waters are discharged, to be elevated and laid dry by subterranean movements. The whole hydrographical basin of the St. Lawrence might be upraised during these convulsions, yet that river might continue, even after so extraordinary a revolution, to drain the same elevated regions, and might still convey its waters in the same direction from the interior of the

continent to the Atlantic. Instead of traversing the lakes, it would hold its course through deposits of lacustrine sand and shelly marl, such as we know to be now forming in Lakes Superior and Erie; and these fresh-water strata would occupy the site and bear testimony to the pristine existence of the lakes. Marine strata may also be brought into view in the space where an inlet of the sea, like the estuary of the St. Lawrence, had once received the continental waters; and in such formations we might discover shells of lacustrine and fluviatile species intermingled with marine testacea and zoophytes.

Subdivisions of strata in the Paris basin. — The area which has been called the Paris basin is about 180 miles in its greatest length from north-east to south-west, and about ninety miles from east to west. This space may be described as a depression in the chalk (see Fig. 62. Vol. III. p. 354.), which has been filled up by alternating groups of marine and freshwater strata. MM. Cuvier and Brongniart attempted in 1811 to distinguish five different formations, and to arrange them in the following order, beginning with the lowest: —

1. First fresh-water formation................	Plastic clay. Lignite. First sandstone.
2. First marine formation	Calcaire grossier.
3. Second fresh-water formation................	Siliceous limestone. Gypsum, with bones of animals. Fresh-water marls.
4. Second marine formation	Gypseous marine marls. Upper marine sands and sandstones. Upper marine marls and limestones.
5. Third fresh-water formation	Siliceous millstone, without shells. Siliceous millstone, with shells. Upper fresh-water marls.

These formations were supposed to have been deposited in succession upon the chalk; and it was imagined that the waters of the ocean had been by turns admitted into and excluded from the same region. But the subsequent investigations of several geologists, especially of M. Constant Prevost *, have led to great modifications in the theoretical views entertained respecting the order in which the several groups were formed; and it now appears that the formations Nos. 1, 2, and 3. of the table of MM. Cuvier and Brongniart, instead of having originated one after the other, are divisible into four nearly contemporaneous groups.

Superposition of different formations in the Paris basin. — A comparison of the two accompanying diagrams will show at a glance the different relations

Fig. 126.

M. Alex. Brongniart.

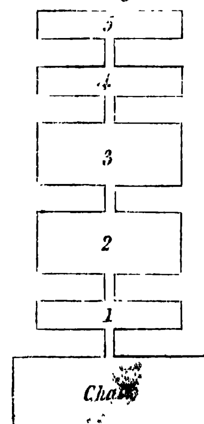
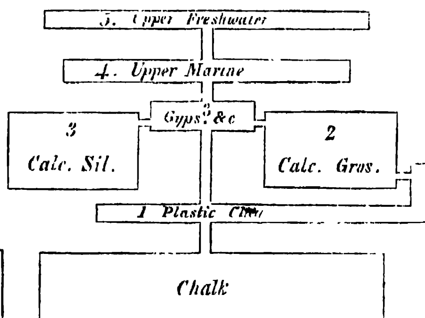


Fig. 127.

M. Constant Prevost.



* Bulletin des Sci. de la Soc. Philom., May, 1825, p. 74.

which the several sets of strata bear to each other, according to the original as well as the more modern classification. I shall now proceed to lay before the reader a brief sketch of the several sets of strata referred to in the above systems.

Immediately upon the chalk a layer of broken chalk flints, often cemented into a breccia by siliceous sand, is very commonly found. These flints probably indicate the action of the sea upon reefs of chalk when a portion of that rock had emerged, and before the regular tertiary beds were superimposed. To this partial layer no reference is made in the annexed sections.

Plastic clay and sand. — Upon this flinty stratum, or, if it be wanting, upon the chalk itself, rests frequently a deposit of clay and lignite (No. 1. of the above tables). It includes the remains of fresh-water shells and drift-wood, and was, at first regarded as a proof that the Paris basin had originally been filled with fresh water. But it has since been shown that this group is not only of very partial extent, but is by no means restricted to a fixed place in the series; for it alternates with the marine calcaire grossier (No. 2. of the tables), and is repeated in the very middle of that limestone at Veaugirard, Bagneux, and other places, where the same Planorbes, Paludinæ, and Limneæ occur.* M. Desnoyers pointed out to me a section in the suburbs of Paris, laid open in 1829, where a similar intercalation was seen in a still higher part of the calcaire grossier. These observations relieve us from the difficulty of seeking a cause why vegetable matter, and certain species of fresh-water shells and a

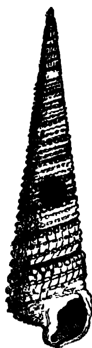
* Prevost, Sur les Submersions Itératives, &c. Mém. de la Soc. d'Hist. Nat. de Paris, tome iv. p. 74.

particular kind of clay, were at first introduced into the basin, and why the same space was subsequently usurped by the sea. A minute examination of the phenomena leads us simply to infer, that a river charged with argillaceous sediment entered a bay of the sea and drifted into it, from time to time, fresh-water shells and wood.

Calcaire grossier. — The calcaire grossier above alluded to, is a coarse limestone, often passing into sand, such as may perhaps have been in part derived from the aqueous degradation of a chalk country. It contains by far the greater number of the fossil shells which characterize the Paris basin. No less than 400 distinct species have been procured from a single spot near Grignon. They are imbedded in a calcareous sand, chiefly formed of comminuted shells, in which, nevertheless, individuals in a perfect state of preservation, both of marine, terrestrial, and fresh-water species, are mingled together, and were evidently transported from a distance. Some of the marine shells may have lived on the spot; but the Cyclostoma and Limnea must have been brought thither by rivers and currents, and the quantity of triturated shells implies considerable movement in the waters.

Nothing is more striking in this assemblage of fossil testacea than the great proportion of species referrible to the genus Cerithium. (See fig. 128.) There occur no less than one hundred and thirty-seven species of this genus in the Paris basin, and almost all of them in the calcaire grossier. Now the living testacea of this genus inhabit the sea near the mouths of rivers, where the waters are brackish, so that their abundance in the marine strata of the Paris basin is in perfect harmony with the hypothesis before advanced

Fig. 128.



*Cerithium cinctum.**

that a river flowed into the gulf, and gave rise to the beds of clay and lignite before mentioned. But there are ample data for inferring that the gulf was supplied with fresh water by more than one river; for while the calcaire grossier occupies the northern part of the Paris basin, another contemporaneous deposit, of fresh-water origin, appears at the southern extremity.

Calcaire siliceux.—This group (No. 3. of the foregoing tables) is a compact siliceous limestone, which resembles a precipitate from the waters of mineral springs. It is often traversed by small empty sinuous cavities; is for the most part devoid of organic remains, but in some places contains fresh-water and land species, and never any marine fossils. The siliceous limestone and the calcaire grossier occupy distinct parts of the basin, the one attaining its fullest development in those places where the other is of slight thickness. They also alternate with each other towards the centre of the basin, as at Sergy and Osny; and there are even points where the two rocks are so blended together, that portions of each may be seen in hand specimens. Thus in the same bed, at Triel, we have the compact fresh-water limestone, characterized by its Limneæ, mingled with the coarse marine limestone through which the small multilocular shell, called milliolite, is dispersed in countless numbers. These microscopic testacea are also accompanied by Cerithia and other shells of the calcaire grossier. It is very extraordinary that in this instance both kinds of sediment must have been thrown down together on the same spot, and each has still retained its own peculiar organic remains.

* This species is found also in the Paris and London basins.

This limestone was pointed out to me by M. Prevost, both *in situ* at Triel, and in hand specimens in his cabinet.

These facts lead irresistibly to the conclusion, that while to the north, where the bay was probably open to the sea, a marine limestone was formed, another deposit of fresh-water origin was introduced to the southward, or at the head of the bay; for it appears that during the Eocene period, as now, the ocean was to the north; and the continent, where the great lakes existed, to the south. From that southern region we may suppose a body of fresh water to have descended charged with carbonate of lime and silica, the water being perhaps in sufficient volume to convert the upper end of the bay into fresh water, like some of the gulfs of the Baltic.

Gypsum and marls. — The next group to be considered is the gypsum, and the white and green marls, subdivisions of No. 3. of the table of Cuvier and Brongniart. These were once supposed to be entirely subsequent in origin to the two groups already considered; but M. Prevost has pointed out that in some localities they alternate repeatedly with the calcaire siliceux, and in others with some of the upper members of the calcaire grossier. The gypsum, with its associated marl and limestone, is in greatest force towards the centre of the basin, where the two groups before mentioned are less fully developed; and M. Prevost infers, that while those two principal deposits were gradually in progress, the one towards the north, and the other towards the south, a river descending from the east may have brought down the gypseous and marly sediment.

It must be admitted, as highly probable, that a bay

or narrow sea, 180 miles in length, would receive, at more points than one, the waters of the adjoining continent; at the same time I may observe, that if the gypsum and associated green and white marls of Montmartre were derived from a hydrographical basin distinct from that of the southern chain of lakes before adverted to, this basin must nevertheless have been placed under circumstances extremely similar; for the identity of the rocks of Velay and Auvergne with the freshwater group of Montmartre, is such as can scarcely be appreciated by geologists who have not carefully examined the structure of both these countries.

Some readers may think that the view above given of the arrangement of four different sets of strata in the Paris basin is far more obscure and complicated than that first presented to them in the system of MM. Cuvier and Brongniart. Undoubtedly the relations of the several groups are less simple than the first observers supposed, being much more analogous to those before described in the lacustrine deposits of Central France. The simultaneous deposition of two or more groups of strata in one basin, some of them fresh-water and others marine, must always produce very complex results; but in proportion as it is more difficult in these cases to discover any fixed order of superposition in the associated mineral masses, so also is it more easy to explain the manner of their origin and to reconcile their relations to the agency of known causes. Instead of the successive irruptions and retreats of the sea, and changes in the chemical nature of the fluid and other speculations of the earlier geologists, we are now simply called upon to imagine a gulf, into one extremity of which the sea entered, and at the other a large river, while other streams may

have flowed in at different points, whereby an indefinite number of alternations of marine and freshwater beds would be occasioned.

Second or Upper marine group.—The next group, called the second or upper marine formation (No. 4. of the tables), consists in its lower division of green marls, which alternate with the fresh-water beds of gypsum and marl last described. Above this division the products of the sea exclusively predominate, the beds being chiefly formed of micaceous and quartzose sand, eighty feet or more in thickness, surmounted by beds of sandstone, with scarcely any limestone. The summits of a great many platforms and hills in the Paris basin consist of this upper marine series.

I fully agree with M. C. Prevost that the alternation of the various marine and fresh-water formations before described admit of a satisfactory explanation without supposing different retreats and subsequent returns of the sea; yet I think that a subsidence of the soil would best account for the position of these upper marine sands. Oscillations of level may have occurred, in consequence of which the sea and a river may have prevailed each in their turn for a time, until at length, by a more considerable sinking down of part of the basin, a tract previously occupied by fresh water was converted into a sea of moderate depth.

In one part of the Paris basin there are decisive proofs that during the Eocene period, and before the upper marine sand was formed, parts of the calcaire grossier were exposed to the action of denuding causes. At Valmondois, for example, a deposit of the upper marine sandstone is found, in which rolled blocks of the calcaire grossier with its peculiar fossils, and fragments of a limestone resembling the calcaire

siliceux, occur.* These calcareous boulders are rolled and pierced by perforating shells belonging to no less than fifteen distinct species. Both the blocks and many worn shells washed out from the calcaire grossier, are found mingled with the ordinary fossils of the upper marine sand.

We have seen that the same earthquake in Cutch could raise one part of the delta of the Indus and depress another, and cause the river to cut a passage through the upraised strata, and carry down the materials removed from the new channel into the sea. All these changes, therefore, might happen within a short interval of time between the deposition of two sets of strata in the same delta.†

It is not improbable, then, that the same convulsions which caused one part of the Paris basin to sink down, so as to let in the sea upon the area previously covered by gypsum and fresh-water marl, may have lifted up the calcaire grossier and the siliceous limestone, so that they might be acted upon by the waves, and fragments of them swept down into the contiguous sea, there to be drilled by boring testacea.

It is observed that the older marine formation at Laon is now raised three hundred metres or nearly one thousand feet above the sea, whereas the upper marine sands never attain half that elevation. Such may possibly have been the relative altitude of the two groups when the newest of them was deposited.

Third fresh-water formation.—We have still to con-

* M. Deshayes, Mémoires de la Soc. d'Hist. Nat. de Paris, tom. i. p. 243. The sandstone is there called, by mistake, grès marin *inférieur*, instead of *supérieur*, to which last the author has since ascertained it to belong.

† Vol. II. p. 237.

sider another formation, the third fresh-water group (No. 5. of the preceding tables). It consists of marls interstratified with beds of flint and layers of flinty nodules. One set of siliceous layers is destitute of organic remains, the other replete with them.

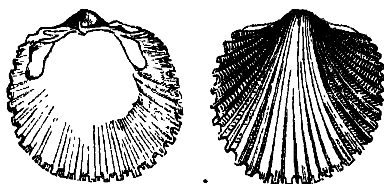
Gyrogonites, or fossil seed-vessels of charæ, are found abundantly in these strata, and all the animal and vegetable remains agree well with the hypothesis, that after the gulf or estuary had been silted up with the sand of the upper marine formation, a great number of marshes and shallow lakes existed, like those which frequently overspread the newest parts of a delta. These lakes were fed by rivers or springs which contained, in chemical solution or mechanical suspension, such kinds of sediment as we have already seen to have been deposited in the lakes of Central France during the Eocene period.

The Parisian groups all Eocene.—Having now given a rapid sketch of the different groups of the Paris basin, I may observe generally that they all belong to the Eocene epoch, although the entire series must doubtless have required an immense lapse of ages for its accumulation. The shells of the different fresh-water groups, constituting at once some of the lowest and uppermost members of the series, are nearly all referrible to the same species, and the discordance between the marine testacea of the calcaire grossier and the upper marine sands is very inconsiderable.

A curious observation has been made by M. Deshayes, in reference to the changes which one species, the *Cardium porulosum*, has undergone during the long period of its existence in the Paris basin. Different varieties of this cardium are characteristic of different strata. In the older sand of the Soissonais (a marine

formation underlying the regular beds of the calcaire grossier), this shell acquires but a small volume, and

Fig. 129.



Cardium porulosum. Paris and London basins.

has many peculiarities, which disappear in the lowest beds of the calcaire grossier. In these the shell attains its full size, and many peculiarities of form, which are again modified in the uppermost beds of the calcaire grossier; and these last characters are preserved throughout the whole of the "upper marine" series.*

Miliolite limestone and microscopic shells.—In some parts of the calcaire grossier round Paris, certain beds occur of a stone used in building, and called by the French geologists *miliolite limestone.* It is almost entirely made up of millions of small shells of the size of minute grains of sand, which all belong to the same class, but are of distinct species from those found in the Older Pliocene beds of Italy. These minute fossil bodies belong to the order *Cephalopoda,* the animals of which are more free in their movements, and more advanced in their organization, than any other mollusca. The multilocular cephalopods have been separated, by D'Orbigny into two subdivisions: first, those having a siphon or internal tube connecting the different chambers, such as the nautilus and ammonite; and, secondly, those without a siphon, to which the microscopic species now under consideration belong. They

* Coquilles caractérist. des Terrains, 1831.

are often in an excellent state of preservation, and their forms are singularly different from those of the larger testacea.

A plate of some of these is given, from unpublished drawings by M. Deshayes, who has carefully selected the most remarkable types of form. The *natural size* of each species figured (Plate XIII.) is indicated by such minute points, that it is necessary to call attention to them, as they might otherwise be overlooked. It should also be mentioned that the genus miliolite of Lamarck has since been subdivided into several genera, among which are the Triloculina and Quinqueloculina figured in the plate (Pl. XIII.).

Characteristic shells.—The species of shells figured in the annexed plate are common in the Paris basin, and may be considered as characteristic of the Eocene period generally. They appear as yet to be exclusively confined to deposits of that period, and are for the most part abundant in them wherever they have been attentively studied. (Pl. XIV.)

Bones of quadrupeds in gypsum.—I have already considered the position of the gypsum which occurs in the form of a saccharoid rock in the hill of Montmartre at Paris, and other central parts of the basin. At the base of that hill it is seen distinctly to alternate with soft marly beds of the calcaire grossier, in which cerithia and other marine shells occur. But the great mass of gypsum may be considered as a purely fresh-water deposit, containing land and fluviatile shells, together with fragments of palm-wood, and great numbers of skeletons of quadrupeds and birds, an assemblage of organic remains which has given great celebrity to the Paris basin. The bones of fresh-water fish, also, and of crocodiles, and many land and fluvia-

tile reptiles, occur in this rock. The skeletons of mammalia are usually isolated, often entire, the most delicate extremities being preserved, as if the carcasses, clothed with their flesh and skin, had been floated down soon after death, and while they were still swoln by the gases generated by their first decomposition. The few accompanying shells are of those light kinds which frequently float on the surface of rivers together with wood.

M. Prevost has therefore suggested that a river may have swept away the bodies of animals, and the plants which lived on its borders, or in the lakes which it traversed, and may have carried them down into the centre of the gulf into which flowed the waters impregnated with sulphate of lime. We know that the Fiume Salso in Sicily enters the sea so charged with various salts that the thirsty cattle refuse to drink of it. A stream of sulphureous water, as white as milk, descends into the sea from the volcanic mountain of Idienne, on the east of Java; and a great body of hot water, charged with sulphuric acid, rushed down from the same volcano on one occasion, and inundated a large tract of country, destroying, by its noxious properties, all the vegetation.* In like manner the Pusanibio, or "Vinegar River," of Colombia, which rises at the foot of Puracé, an extinct volcano 7500 feet above the level of the sea, is strongly impregnated with sulphuric and muriatic acids, and with oxide of iron. We may easily suppose the waters of such streams to have properties noxious to marine animals,

* Leyde Magaz. voor Wetensch Konst en Lett., partie v. cahier i. p. 71. Cited by Rozet, Journ. de Géologie, tom. i. p. 43.

and in this manner the entire absence of marine remains in the ossiferous gypsum may be explained.*

There are no pebbles or coarse sand in the gypsum; a circumstance which agrees well with the hypothesis that these beds were precipitated from water holding sulphate of lime in solution, and floating the remains of different animals. The bones of land quadrupeds, however, are not confined entirely to the fresh-water formation to which the gypsum belongs; for the remains of a Palæotherium, together with some fresh-water shells, have been found in a marine stratum belonging to the calcaire grossier at Beauchamp.

In the gypsum the remains of about fifty species of quadrupeds have been found, all extinct, and nearly four-fifths of them belonging to a division of the order Pachydermata, which is now represented by only four living species; namely, three tapirs and the daman of the Cape. With them a few carnivorous animals are associated, among which are a species of fox and gennet. Of the Rodentia, a dormouse and a squirrel; of the Insectivora, a bat; and of the Marsupialia (an order now confined to America, Australia, and some contiguous islands), an opossum, have been discovered.

Of birds, about ten species have been ascertained, the skeletons of some of which are entire. None of them are referrible to existing species.† The same remark applies to the fish, according to MM. Cuvier and Agassiz, as also to the reptiles. Among the last are crocodiles and tortoises of the genera Emys and Trionix.

The tribe of land quadrupeds most abundant in this

* M. C. Prevost, Submersions Itératives, &c. Note 23.
† Cuvier, Oss. Foss., tom. iii. p. 255.

formation is such as now inhabits alluvial plains and marshes and the banks of rivers and lakes, a class most exposed to suffer by river inundations. Whether the disproportion of carnivorous animals can be ascribed to this cause, or whether they were comparatively small in number and dimensions, as in the indigenous fauna of Australia, when first known to Europeans, is a point on which it would be rash perhaps to offer an opinion in the present state of our knowledge.

We have no reason to be surprised that all the species of vertebrated animals hitherto observed are extinct, when we recollect that out of 1122 species of fossil testacea obtained from the Paris basin, thirty-eight only can be identified with species now living. I have more than once adverted to the fact, that extinct mammalia are often found associated with assemblages of *recent* shells, a fact from which I have inferred the inferior duration of species of the mammalia as compared with the testacea; and it is not improbable that the higher order of animals in general may more readily become extinct than the marine mollusca. Some of the thirty-eight species of testacea above alluded to, as having survived from the Eocene period to our own times, have now a wide geographical range, as, for example, *Lucina divaricata* *, and are therefore fitted to exist under a great variety of circumstances. On the other hand, the great proportion of the Eocene marine testacea which have become extinct sufficiently demonstrates that the loss of species has been due to general laws; and that a sudden catastrophe, such as the invasion of a whole continent by the sea—a cause which could annihilate only the terrestrial and fresh-

* See Fig. 65. Vol. III. p. 394.

water tribes, is an hypothesis wholly inadequate to account for the phenomenon.

Strata with and without organic remains alternating. — Between the gypsum of the Paris basin and the upper marine sands a thin bed of oysters is found, which is spread over a remarkably wide area. From the manner in which they lie, it is inferred that they did not grow on the spot, but that some current swept them away from a bed of oysters formed in some other part of the bay. The strata of sand which immediately repose on the oyster-bed are quite destitute of organic remains; and nothing is more common in the Paris basin and in other formations, than alternations of shelly beds with others entirely devoid of them. The temporary extinction and renewal of animal life at successive periods have been inferred from such phenomena, which may nevertheless be explained, as M. Prevost justly remarks, without appealing to any such extraordinary revolutions in the state of the animate creation. A current one day scoops out a channel in a bed of shelly sand and mud, and the next day, by a slight alteration of its course, ceases to prey upon the same bank. It may then become charged with sand unmixed with shells, derived from some dune, or brought down by a river. In the course of ages an indefinite number of transitions from shelly strata to those without shells may thus be caused.

Concluding remarks.—It will be seen by our observations on Auvergne and other parts of Central France, and on the district round Paris, that geologists have already gained a considerable insight into the state of the physical geography of part of Europe during the Eocene period. We can point to some districts where lakes and rivers then existed, and to the site of

some of the lands encircling those lakes, and to the position of a great bay of the sea, into which their surplus waters were discharged. We can also show, as I shall endeavour to explain in the next chapter, the points where some volcanic eruptions took place. Much information has been acquired respecting the quadrupeds which inhabited the land at that period, and concerning the reptiles, fishes, and testacea which swarmed in the waters of lakes and rivers; and we have a collection of the marine Eocene shells more complete than has yet been obtained from any existing sea of equal extent in Europe. Nor are the contemporary fossil plants altogether unknown to us, which, like the animals, are of extinct species, and indicate a warmer climate than that now prevailing in the same latitudes.

When we reflect on the tranquil state of the earth, implied by some of the lacustrine and marine deposits of this age, and consider the fulness of all the different classes of the animal kingdom, as deduced from the study of the fossil remains, we are naturally led to conclude, that the earth was at that period in a perfectly settled state, and already fitted for the habitation of man.

The heat of European latitudes during the Eocene period does not seem to have been superior, if equal, to that now experienced between the tropics; some *living* species of molluscous animals, both of the land, the lake, and the sea, existed when the strata of the Paris basin were formed; and the contrast in the organization of the various tribes of Eocene animals, when compared to those now co-existing with man, although striking, is not, perhaps, so great as between the living Australian and European types. At the

same time, we must be fully aware that we cannot reason with any confidence on the capability of our own, or any other contemporary species, to exist under circumstances so different as those which might be caused by an entirely new distribution of land and sea; and we know that in the earlier tertiary periods the physical geography of the northern hemisphere was very distinct. Our inability to account for the atmospheric and other latent causes, which often give rise to the most destructive epidemics, proves the extent of our ignorance of the entire assemblage of conditions requisite for the existence of any one species on the globe.

CHAPTER XIX.

EOCENE VOLCANIC ROCKS.

Volcanic rocks of Auvergne — Eruptions at successive periods — Mont Dor an extinct volcano — Velay — Plomb du Cantal, (p. 204.) — Train of minor volcanos stretching from Auvergne to the Vivarais — Monts Domes — Ravines excavated through lava — Alluviums of distinct ages (p. 209.) — Age of more modern lavas of Central France — No eruption during the historical era — Division of volcanos into ante-diluvian and post-diluvian inadmissible — Theories respecting the effects of the Flood considered (p. 214.) — Recapitulation.

In treating of the lacustrine deposits of Central France, in the seventeenth chapter, I omitted, in order to avoid confusion, all details respecting the associated volcanic rocks, to which I now recall the reader's attention. (See the Map, p. 158.)

It was stated that, in the arenaceous and pebbly group of the lacustrine basins of Auvergne, Cantal, and Velay, no volcanic pebbles had ever been detected, although massive piles of igneous rocks are now found in the immediate vicinity. As this observation has been confirmed by minute research, we are warranted in inferring that the volcanic eruptions had not commenced when the older subdivisions of the fresh-water groups originated.

In Cantal and Velay no decisive proofs have yet been brought to light that any of the igneous outbursts happened during the deposition of the fresh-

water strata; but there can be no doubt that in Auvergne some volcanic explosions took place before the drainage of the lakes, and at a time when the Eocene species of animals and plants still flourished. I shall first advert to these proofs, as relating to the history of the period under consideration, and shall then proceed to show that there are in the same country volcanic rocks of much newer date, some of which appear to be referrible to the Miocene era.

Volcanic rocks associated with lacustrine in Auvergne. — The first locality to which I shall call the reader's attention is Pont du Chateau, near Clermont, which spot, as well as all the others in Auvergne, mentioned in this chapter, I examined, in company with Mr. Murchison, in 1828. The section at this place is seen in a precipice on the right bank of the river Allier. Here beds of volcanic tuff alternate with a fresh-water limestone, which is in some places pure, but in others spotted with fragments of volcanic matter, as if it were deposited while showers of sand and scoriæ were projected from a neighbouring vent.* This limestone contains the *Helix Ramondi* and other shells of Eocene species. It is immaterial to the present argument whether the volcanic sand was showered down from above, or drifted to the spot by a river; for the latter opinion must presuppose the country to have been covered with volcanic ejections during the Eocene period.

Another example occurs in the Puy de Marmont, near Veyres, where a fresh-water marl alternates with volcanic tuff containing Eocene shells. The tuff or breccia in this locality is precisely such as is known to

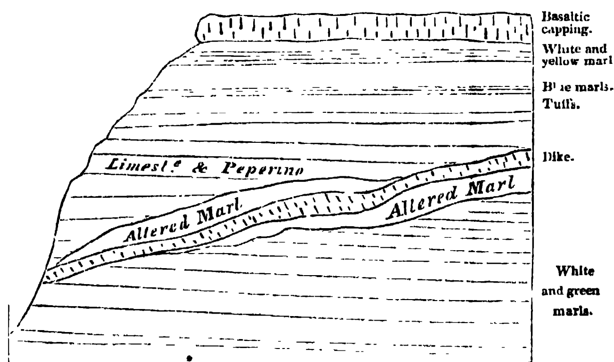
* See Scrope's Central France, p. 21.

result from volcanic ashes falling into water, and subsiding together with ejected fragments of marl and other stratified rocks. These tuffs and marls are highly inclined, and traversed by a thick vein of basalt, which, as it rises in the hill, divides into two branches.

Gergovia. — The hill of Gergovia, near Clermont, affords a third example. I agree with MM. Dufrénoy d Jobert that there is no alternation here of lava and fresh-water strata, in the manner supposed by some other observers *; but the position and contents of some of the tuffs prove them to have been derived from volcanic eruptions which occurred during the deposition of the Eocene formations.

The bottom of the hill consists of slightly inclined beds of white and greenish marls, more than three hundred feet in thickness, intersected by a dike of basalt, which may be studied in the ravine above the village of Merdogne. The dike here cuts through the

Fig. 130.



Hill of Gergovia.

See Scrope's Central France, p. 7.

marly strata at a considerable angle, producing, in general, great alteration and confusion in them for some distance from the point of contact. Above the white and green marls, a series of beds of limestone and marl, containing fresh-water shells, are seen to alternate with volcanic tuff. In the lowest part of this division, beds of pure marl alternate with compact fissile tuff, resembling some of the subaqueous tuffs of Italy and Sicily called *peperinos*. Occasionally fragments of scoriæ are visible in this rock. Still higher is seen another group of some thickness, consisting exclusively of tuff, upon which lie other marly strata intermixed with volcanic matter.

There are many points in Auvergne where igneous rocks have been forced by subsequent injection through clays and marly limestones, in such a manner that the whole has become blended in one confused and brecciated mass, between which and the basalt there is sometimes no very distinct line of demarcation. In the cavities of such mixed rocks we often find calcedony, and crystals of mesotype, stilbite, and arragonite. To formations of this class may belong some of the breccias immediately adjoining the dike in the hill of Gergovia; but it cannot be contended that the volcanic sand and scoriæ interstratified with the marls and limestones in the upper part of that hill were introduced, like the dike, subsequently, by intrusion from below. They must have been thrown down like sediment from water, and can only have resulted from igneous action, which was going on contemporaneously with the deposition of the lacustrine strata.

The reader will bear in mind that this conclusion agrees well with the proofs, adverted to in the seventeenth chapter, of the abundance of silex, travertin,

and gypsum precipitated when the upper lacustrine strata were formed; for these rocks are such as the waters of mineral and thermal springs might generate.

The igneous products above mentioned, as associated with the lacustrine strata, form the lowest members of the great series of volcanic rocks of Auvergne, Cantal, and Velay, which repose for the most part on the granitic mountains (see Map above, p. 158.). There was evidently a long succession of eruptions, beginning with those of the Eocene period, and ending, so far as can yet be inferred from the evidence derived from fossil remains, with those of the Miocene epoch. The oldest part of the two principal volcanic masses of Mont Dor and the Plomb du Cantal may perhaps belong to the Eocene period, — the newer portion of the same mountains to the Miocene; just as Etna commenced its operations during the Newer Pliocene era, and has continued them down to the Recent epoch, and still retains its energy undiminished. There are some parts of the Mont Mezen, in Velay, which are perhaps of the same antiquity as the oldest parts of Mont Dor.

Besides these ancient rocks, of which the lavas are in a great measure trachytic, there are many minor cones in Central France, for the most part of posterior origin, which extend from Auvergne, in a direction north-west and south-east, through Velay, into the Vivarais, where they are seen in the basin of the Ardêche. This volcanic line does not pass by the Plomb du Cantal; it was formed, as nearly as can be conjectured in the present imperfect state of our knowledge, during the Miocene period; but there may probably be found, among these cones and their accompanying lavas, rocks of every intermediate age between

the oldest and newest volcanic formations of Central France.

I shall first give a brief description of the Mont Dor and the Plomb du Cantal, and then pass on to the train of newer cones, examining the evidence at present obtained respecting their relative ages, and the light which they throw on the successive formation of alluviums and on the excavation of valleys.

Mont Dor. — Mont Dor, the most conspicuous of the volcanic masses of Auvergne, rests immediately on the granitic rocks standing apart from the fresh-water strata.* This volcano rises suddenly to the height of several thousand feet above the surrounding platform, and retains the shape of a flattened and somewhat irregular cone, all the sides sloping more or less rapidly, until their inclination is gradually lost in the high plain around. This cone is composed of layers of scoriæ, pumice-stones, and their fine detritus, with interposed beds of trachyte and basalt, which descend often in uninterrupted currents, till they reach and spread themselves round the base of the mountain. † Conglomerates also, composed of angular and rounded fragments of igneous rocks, are observed to alternate with the above; and the various masses are seen to dip off from the central axis, and to lie parallel to the sloping flanks of the great cone, in the manner I have described when treating of Etna.

The summit of the mountain terminates in seven or eight rocky peaks, where no regular crater can now be traced, but where we may easily imagine one to have existed, which may have been shattered by earthquakes, and have suffered degradation by aqueous

* See the Map, p. 158.

† Scrope's Central France, p. 98.

agents. Originally, perhaps, like the highest crater of Etna, it may have formed an insignificant feature in the great pile, and may frequently have been destroyed and renovated.

We cannot at present determine the age of the great mass of Mont Dor, because no organic remains have yet been found in the tuffs, except impressions of the leaves of trees, of species not determined. Some of the lowest parts of the mountain are formed of white pumiceous tuffs, in which animal remains may perhaps be one day found. In the mean time, we may conclude that Mont Dor had no existence when the grits and conglomerates of the Limagne, which contain no volcanic materials, were formed; but some of the earliest eruptions were, perhaps, contemporary with those described in the commencement of this chapter. To the latest of these eruptions, on the other hand, I refer those trachytic breccias of Mont Perrier, which were shown in the sixteenth chapter (p. 147.) to alternate with Miocene alluviums.

Velay. — The observations of M. Bertrand de Doue have not yet established that any of the most ancient volcanos of Velay were in action during the Eocene period, although it is very probable that some of them may have been contempo·aneous with the oldest of the Auvergne lavas. There are beds of gravel in Velay, as in Auvergne, covered by lava at different heights above the channels of the existing rivers. In the highest and most ancient of these alluviums the pebbles are exclusively of granitic rocks; but in the newer, which are found at lower levels, they contain an intermixture of volcanic substances. I have already shown, in the sixteenth chapter, that, in the volcanic ejections and alluviums covered by the lavas of Velay, the bones

of animals of Miocene species have been found, in which respect the phenomena accord perfectly with those of Auvergne.

Plomb du Cantal. — In regard to the age of the igneous rocks of the Cantal we are still less informed, and at present can merely affirm, that they overlie the Eocene lacustrine strata of that country. (See Map, Fig. 120.) They form a great dome-shaped mass, which has evidently been accumulated, like the cone of Etna, during a long series of eruptions. It is composed of trachytic, phonolitic, and basaltic lavas, tuffs, and conglomerates, or breccias, forming a mountain several thousand feet in height. Dikes also of phonolite, trachyte, and basalt are numerous, especially in the neighbourhood of the large cavity, probably once a crater, around which the loftiest summits of the Cantal are ranged circularly, few of them, except the Plomb du Cantal, rising far above the border or ridge of this supposed crater. A pyramidal hill, called the Puy Griou, occupies the middle of the cavity.* It is evident that the volcano of the Cantal broke out precisely on the site of the lacustrine deposit before described (Chapter xvii.), which had accumulated in a depression of a tract composed of micaceous schist. In the breccias, even to the very summit of the mountain, we find ejected masses of the fresh-water beds, and sometimes fragments of flint, containing Eocene shells. Valleys radiate in all directions from the central heights of the mountain, increasing in size as they recede from those heights. Those of the Cer and Jourdanne, which are more than twenty miles in length, are of great depth, and lay open the geological structure of the mountain.

* Mém. de la Soc. Géol. de France, tom. i. p. 175.

No alternation of lavas with undisturbed Eocene strata has been observed, nor any tuffs containing fresh-water shells, although some of these tuffs include fossil remains of terrestrial plants said to imply several distinct restorations of the vegetation of the mountain in the intervals between great periods of eruption. On the northern side of the Plomb du Cantal, at La Vissiere, near Murat, is a spot, pointed out on the Map (p. 158.), where fresh-water limestone and marl are seen covered by a thickness of about eight hundred feet of volcanic rock. Shifts are here seen in the strata of limestone and marl.*

Although it appears that the lavas of the Cantal are more recent than the fresh-water formation of that country, it does not follow that they may not belong to the Eocene period. The lake may possibly have been drained by the earthquakes which preceded or accompanied the first eruptions, but the Eocene animals and plants may have continued to exist for a long series of ages, while the cone went on increasing in dimensions.

Train of minor volcanos. — I shall next consider those minor volcanos, before alluded to, which stretch in a long range from Auvergne to the Vivarais, and which appear for the most part to be of newer origin than the mountains above described. These volcanos were faithfully described, so early as the year 1802, by M. de Montlosier. † They have been thrown up in a great number of isolated points, and much resemble those scattered over the Phlegræan fields and the flanks of Etna. They have given rise chiefly to currents of

* See Lyell and Murchison, Ann. des Sci. Nat., Oct. 1829.

† Théorie des Volc. d'Auvergne. — Clermont, An X.

basaltic lava, whereas those of Mont Dor and the Cantal are in great part trachytic. There are perhaps about 300 of these minor cones in Central France; but a part of them only occur in Auvergne, where some few are found at the bottom of valleys excavated through the more ancient lavas of Mont Dor, as the Puy de Tartaret, for example, whence issues a current of lava which, flowing into the bed of the river Couze, gave rise to the lake of Chambon. Here the more ancient columnar basalts of Auvergne are seen forming the upper portion of the precipices which bound the valley.

But the greater part of the minor cones of Auvergne are placed upon the granitic platform, where they form an irregular ridge, about eighteen miles in length and two in breadth. They are usually truncated at the summit, where the crater is often preserved entire, the lava having issued from the base of the hill. But frequently the crater is broken down on one side, where the lava has flowed out. The hills are composed of loose scoriæ, blocks of lava, lapilli, and puzzuolana, with fragments of trachyte and granite.

The lavas may be often traced from the crater to the nearest valley, where they usurp the channel of the river, which has often excavated a deep ravine through the basalt. We have thus an opportunity of contrasting the enormous degradation which the solid and massive rock has suffered by aqueous erosion, and the integrity of the cone of sand and ashes which has, in the mean time, remained uninjured on the neighbouring platform, where it was placed beyond the reach of the power of running water.

Puy de Côme. — The Puy de Côme and its lava current, near Clermont, may be mentioned as one of the

numerous illustrations of the phenomenon here alluded to.* This conical hill rises from the granitic platform, at an angle of about 40°, to the height of more than 900 feet. Its summit presents two distinct craters, one of them with a vertical depth of 250 feet. A stream of lava takes its rise at the western base of the hill, instead of issuing from either crater, and descends the granitic slope towards the present site of the town of Pont Gibaud. Thence it pours in a broad sheet down a steep declivity into the valley of the Sioule, filling the ancient river-channel for the distance of more than a mile. The Sioule, thus dispossessed of its bed, has worked out a fresh one between the lava and the granite of its western bank; and the excavation has disclosed, in one spot, a wall of columnar basalt about 50 feet high. †

The excavation of the ravine is still in progress, every winter some columns of basalt being undermined and carried down the channel of the river, and in the course of a few miles rolled to sand and pebbles. Meanwhile the cone of Côme remains stationary, its loose materials being protected by a dense vegetation, and the hill standing on a ridge not commanded by any higher ground whence floods of rain-water may descend.

Puy Rouge. — At another point, farther down the course of the Sioule, we find a second illustration of the same phenomenon in the Puy Rouge, a conical hill to the north of the village of Pranal. The cone is composed entirely of red and black scoriæ, tuff, and volcanic bombs. On its western side there is a worn-down

* Montlosier, Théorie des Volc. d'Auvergne, ch. ii.

† Scrope's Central France, p. 60., and plate.

crater, whence a powerful stream of lava has issued, and flowed into the valley of the Sioule. The river has since excavated a ravine through the lava and subjacent gneiss, to the depth of 400 feet.

On the upper part of the precipice forming the left side of this ravine, we see a great mass of black and red scoriaceous lava; below this a thin bed of gravel, evidently an ancient river-bed, now at an elevation of fifty feet above the channel of the Sioule. The gravel again rests upon gneiss, which has been eroded to the depth of 50 feet.* It is quite evident in this case, that, while the basalt was gradually undermined and carried away by the force of running water, the cone whence the lava issued escaped destruction, because it stood upon a platform of gneiss several hundred feet above the level of the valley in which the force of running water was exerted.

It is needless to multiply examples, or the Vivarais would supply many others equally striking. Among many I may instance the cone of Jaujac, and its lava current, which is a counterpart of that near Pranal last mentioned.†

Lavas and alluviums of different ages. — We have seen that on the flanks of Etna, since the commencement of the present century, several currents of lava have flowed at the bottom of the Val del Bove, at the foot of precipices formed of more ancient lavas and tuffs. So we find in Auvergne that some streams of melted matter have flowed in valleys, the sides of which consist partly of older lavas. These are often

* See Lyell and Murchison on the Excavation of Valleys, Edin. New Phil. Journ., July, 1829.

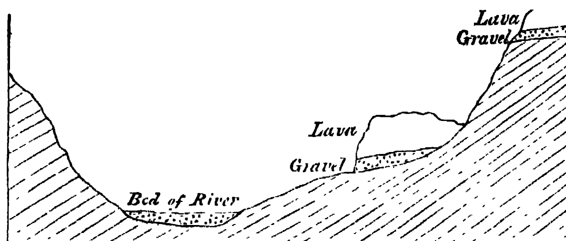
† Scrope's Central France, plate 14.

seen capping the hills in broad sheets, resting sometimes on granite, sometimes on fresh-water strata.

Many of the earlier lavas of Auvergne flowed out upon the platform of granite before all the existing valleys had been excavated; others again spread themselves in broad sheets over the horizontal lacustrine deposit, when these had been covered with gravel, probably soon after the drainage of the lakes. Great vicissitudes in the physical geography of the country must have taken place since the flowing of these ancient lavas; and it is evident that the changes were gradual and successive, caused probably by the united agency of running water and subterranean movements. We frequently observe one mass of lava capping a hill, and a second at a lower elevation, forming a terrace on the side of a valley; or sometimes occupying the bed of a river.

It is a most interesting fact, that in these cases beds of gravel almost invariably underlie the successive currents of lava, as in Catalonia before described (pp. 108. 111.). Occasionally, when the highest platform of lava is seven hundred or eight hundred feet above the lowest, we cannot fail to be struck with the

Fig. 131.



Lavas of Auvergne resting on alluviums of different ages.

wonderful alterations effected in the drainage of the country since the first current flowed; for the most elevated alluviums must originally have been accumulated on the lowest levels of the then existing surface. As some geologists have referred almost all the superficial gravels to one era, and have supposed them to be the result of one sudden catastrophe, the phenomena of Auvergne here alluded to are very important. The flows of volcanic matter have, in fact, preserved portions of the surface in the state in which they existed at successive periods; so that it is impossible to confound together the alluviums of different ages. The reader will see at once, by reference to the woodcut (Fig. 131.), that a considerable interval of time must have occurred between the formation of the uppermost bed of gravel and that next below it; during which interval the uppermost lava was poured out, and a valley excavated, at the bottom of which the second bed of gravel accumulated. In like manner the pouring out of a second current of lava, and a farther deepening of the valley, took place between the date of the second gravel and that of the modern alluvium which now fills the channel of the river.*

When rivers are dispossessed of their channels by lava, they usually flow between the mass of lava and one side of the original valley. They there eat out a passage, partly through the volcanic and partly through the older formation; but as the soft tertiary marls

* For localities in Central France where lavas or sheets of basalt repose on alluviums at different elevations above the present valleys, and for the inferences deducible from such facts, consult the works of MM. Le Grand d'Aussi, Montlosier, Ramond, Scrope, Bertrand de Doue, Croizet, Jobert, and Bouillet.

in Auvergne give way more readily than the basalt, it is usually at the expense of the marls that the enlarging and deepening of the new valley is effected; so that all the remaining lava is then left on one side, in the manner represented in the above woodcut.

Alluviums in ancient fissures.—It might have been expected, from the analogy of modern changes in volcanic countries, that we should find in Auvergne some signs of ancient fissures caused by earthquakes. Accordingly M. Fournet has observed in the course of excavations made for mining in the valley of the Sioule, near Clermont, some curious and decisive proofs of the former existence of open rents which must have communicated with the surface, and have been filled from above with alluvium, after the commencement and before the end of the period of volcanic eruptions. It appears that a metaliferous vein traversing gneiss (in other words, a mass or dike of matter, partly metallic and partly not, filling an old fissure in the gneiss) had been dislocated by later convulsions, so that a new rent was formed in it which reached the surface. Sand and gravel like that of a river-bed were then washed in, together with pieces of wood, which are now found fossil with the gravel, in a good state of preservation. The rounded pebbles are partly of granitic rocks, partly of basaltic and augitic lava, showing that the last filling up of the fissure occurred after some lavas had flowed over the adjacent country. But two of the most modern lava streams near Pont Gibaud, have passed over the top of the dike, and they must evidently have been poured out after it was filled with alluvium.*

* See Fournet, Traité de Geog., D'Aubuisson, tom. iii. p. 544.

Age of the more modern lavas.—The only organic remains found as yet in the ancient alluviums appear to belong to the Miocene period; but I have heard of none discovered in the gravel underlying the newest lavas,—those which either occupy the channels of the existing rivers, or are very slightly elevated above them. I think it not improbable that even these may be of Miocene date, although the conjecture will appear extremely rash to some who are aware that the cones and craters whence the lavas issue are often as fresh in their aspect as the majority of the cones of the forest zone of Etna.

The brim of the crater of the Puy de Pariou, near Clermont, is so sharp, and has been so little blunted by time, that it scarcely affords room to stand upon. This and other cones in an equally remarkable state of integrity have stood, I conceive, uninjured, not *in spite* of their loose porous nature, as might at first be naturally supposed, but in consequence of it. No rills can collect where all the rain is instantly absorbed by the sand and scoriæ, as was shown to be the case on Etna (see Vol. III. p. 455.); and nothing but a water-spout breaking directly upon the Puy de Pariou could carry away a portion of the hill, so long as it is not rent or engulphed by earthquakes.

Attempt to divide volcanos into ante-diluvian and post-diluvian.—The opinions above expressed are entirely at variance with the doctrines of those writers who have endeavoured to arrange all the volcanic cones of Europe under two divisions, those of ante-diluvian and those of post-diluvian origin. To the ante-diluvian class they attribute such hills of sand and scoriæ as exhibit on their surface evident signs of aqueous denudation; to the post-diluvian, such as betray no marks

of having been exposed to such aqueous action. According to this classification, almost all the minor cones of Central France must be called post-diluvian; although, if we receive this term in its ordinary acceptation, as denoting posteriority of date to the Noachian deluge, we are forced to suppose that all the volcanic eruptions occurred within a period of little more than twenty centuries, or between the era of the flood, which happened about four thousand years ago, and the earliest historical records handed down to us respecting the former state of Central France. Dr. Daubeny has justly observed, that had any of these French volcanos been in a state of activity in the age of Julius Cæsar, that general, who encamped upon the plains of Auvergne, and laid siege to its principal city (Gergovia, near Clermont), could hardly have failed to notice them. Had there been even any record of their existence in the time of Pliny or Sidonius Apollinaris, the one would scarcely have omitted to make mention of it in his Natural History, nor the other to introduce some allusion to it among the descriptions of this his native province. This poet's residence was on the borders of the Lake Aidat, which owed its very existence to the damming up of a river by one of the most modern lava-currents.*

The ruins of several Roman bridges, and of the Roman baths at Royat, confirm the conclusion that no sensible alteration has taken place in the physical geography of the district, not even in the chasms excavated through the newest lavas since ages historically remote. We have no data at present for

* Daubeny on Volcanos, p. 14.

presuming that any one of the Auvergne cones has been produced within the last four or five thousand years; and the same may be said of those of Velay; and, until the bones of men or articles of human workmanship are found buried under some of their lavas, instead of the remains of extinct animals, which alone have hitherto been met with, we are justified in regarding it as probable that the latest of the volcanic eruptions may have occurred during the Miocene period.

Supposed effects of the Flood.

They who have used the terms ante-diluvian and post-diluvian, in the manner above adverted to, proceed on the assumption that there are clear and unequivocal marks of the passage of a general flood over all parts of the surface of the globe. It had long been a question among the learned, even before the commencement of geological researches, whether the deluge of the Scriptures was universal in reference to the whole surface of the globe, or only so with respect to that portion of it which was then inhabited by man. If the latter interpretation be admissible, it will appear from other parts of this work that there are two classes of phenomena in the configuration of the earth's surface, which might enable us to account for such an event. First, extensive lakes elevated above the level of the ocean; secondly, large tracts of dry land depressed below that level. When there is an immense lake, having its surface, like Lake Superior, raised six hundred feet above the level of the sea, the water may be suddenly let loose by the rending or sinking down of the barrier during earthquakes, and hereby a region

as extensive as the valley of the Mississippi, inhabited by a population of several millions, might be deluged.* On the other hand, if there be any country placed beneath the mean level of the ocean, as some have supposed to be the case with part of Asia†, the depressed region must be entirely laid under water, if the tract which separates it from the ocean be fissured or depressed to a certain depth. Humboldt inferred, from the observations of Parrot, that a great cavity existed in Western Asia, eighteen thousand square leagues in area, and occupied by a considerable population.‡ The lowest parts, surrounding the Caspian Sea, were said to be about 350 feet below the level of the Euxine,—here, therefore, the diluvial waters might overflow the summits of hills rising 350 feet above the level of the plain; and if depressions still more profound existed in any former time in Asia, the tops of still loftier mountains may have been covered by a flood.§

* Vol. I. p. 130. † Vol. III. p. 148.

‡ Fragmens Asiatiques, Paris, 1831.

§ While this sheet was passing through the press I received a copy of the "Reise zum Ararat," just published by Professor Parrot, of Dorpat; and was surprised to find that he doubts, nay appears wholly to have disproved the fact so long believed on his authority, of a difference of level between the Black Sea and the Caspian. The opinion was originally adopted on the authority of barometrical measurements, made by him and M. Engelhardt in 1811. M. Parrot, however, on revisiting the country in 1829 and 1830, was led to suspect the correctness of his former observations on several grounds, one of which only I shall now quote. Russian engineers had ascertained by accurate measurements, that the Don, at the place called Katschalinsk, where it is only sixty wersts distant from the Wolga, is 130 Paris feet *higher* than the latter river, and that the Don flows with much greater rapidity to the Black Sea than the Wolga does to the Caspian; con-

But the great majority of the older commentators have held the deluge, according to the brief account of the event given by Moses, to have consisted of a rise of waters over *the whole earth*, by which the summits of the loftiest mountains on the globe were submerged. Many have indulged in speculations concerning the instruments employed to bring about the grand cataclysm; and there has been a great division of opinion as to the effects which it might be expected to have produced on the surface of the earth. According to one school, of which De Luc in former times, and more recently Dr. Buckland, have been zealous supporters, the passage of the flood worked a considerable alteration in the external configuration of our continents. By Dr. Buckland the deluge has been represented as a violent and transient rush of waters which tore up the soil to a great depth, excavated valleys, gave rise to immense beds of shingle, carried fragments of rock and gravel from one point to another; and, during its advance and retreat, strewed the

sequently, if there be a difference of level of the two seas, it must be considerably less than 130 feet. Parrot accordingly, determined to ascertain the truth, made a series of levellings from the mouth of the Wolga to Zarytzin, 400 wersts up its course, and from the mouth of the Don to the like distance. The result was that he made the mouth of the Don between three and four feet *lower* than that of the Wolga! Baron Humboldt, who with other geographers had given full credit to the former statement of Parrot, refused to admit the validity of these new results, unless the professor was prepared to show that his former observations were less worthy of confidence. In reply to this, Parrot, in an Appendix, admits that their barometrical instruments used in 1811 were not quite perfect, that some errors had crept into his calculations, that he was suffering from ill health, &c. &c.

valleys, and even the tops of many hills, with alluvium.*

But I agree with Dr. Fleming, that in the narrative of Moses there are no terms employed that indicate the impetuous rushing of the waters, either as they rose or when they retired, upon the restraining of the rain and the passing of a wind over the earth.† On the contrary, the olive-branch, brought back by the dove, seems as clear an indication to us that the vegetation was not destroyed, as it was then to Noah that the dry land was about to appear.

I have been led with great reluctance into this digression, in the hope of relieving the minds of some readers from groundless apprehension respecting the bearing of many of the views advocated in this work. They have been in the habit of regarding the diluvial theory above controverted as alone capable of affording an explanation of geological phenomena in accordance with Scripture, and they may have felt disapprobation at an attempt to prove, in a former chapter, that the minor volcanos on the flanks of Etna may, some of them, be more than 10,000 years old.‡ How, they would immediately ask, could they have escaped the denuding force of a diluvial rush of waters? The same objection may have presented itself when I quoted, with respect, the opinion of a distinguished botanist, that some living specimens of the Baobab tree of

* Buckland, Reliquiæ Diluvianæ.

† See a Memoir by the Rev. John Fleming, D. D., on the Geological Deluge, Edin. Phil. Journ., vol. xiv. p. 205. His opinions were reviewed by the author of the present volume in Oct. 1827, in an article in the Quarterly Review, No. lxxii. p. 481.

‡ Vol. III. p. 453.

Africa, or the Taxodium of Mexico, may be 5000 years old.* The reader may also have been astonished at the high antiquity assigned to the greater part of the European alluviums, and the many different ages to which I have referred them†, as he may have been taught to consider the whole as the result of one *recent* and *simultaneous* inundation.

Professor Sedgwick is inclined to adopt the hypothesis of M. Elie de Beaumont, that the sudden elevation of mountain-chains "has been followed again and again by mighty waves desolating whole regions of the earth‡;" a phenomenon which he thinks has "taken away all anterior incredibility from the fact of a recent deluge."§

But I cannot admit that there are sufficient geological data for inferring such instantaneous upheavings of submerged land as might be capable of causing a flood over a whole continent at once. I may also observe, that the reasoning above alluded to seems to proceed entirely on the assumption that the flood of Noah was brought about by *natural* causes, just as some writers have contended that a volcanic eruption was the instrument employed to destroy Sodom and Gomorrah. If we believe the flood to have been a temporary suspension of the ordinary laws of the natural world, requiring a miraculous intervention of Divine power, then it is evident that the credibility of such an event cannot be enhanced by any series of inundations, however analogous, of which the geologist may imagine that he has discovered the proofs.

* See Vol. III. p. 451.

† Vol. IV. p. 58. ‡ Vol. III. p. 454.

§ Sedgwick, Anniv. Address to the Geol. Soc., Feb. 18th, 1831.

For my own part, I have always considered the flood, when its universality in the strictest sense of the term is insisted upon, as a preternatural event far beyond the reach of philosophical inquiry, whether as to the causes employed to produce it, or the effects most likely to result from it. At the same time, it is clear that they who are desirous of pointing out the coincidence of geological phenomena with the occurrence of such a general catastrophe, must neglect no one of the circumstances enumerated in the Mosaic history, least of all so remarkable a fact as that the olive remained standing while the waters were abating.

Recapitulation. — I shall now briefly recapitulate some of the principal conclusions to which we have been led by an examination of the volcanic districts of Central France.

1st. Some of the volcanic eruptions of Auvergne took place during the Eocene period; others at an era long subsequent, probably during the Miocene period.

2ndly. There are no proofs as yet discovered that the most recent of the volcanos of Auvergne and Velay are subsequent to the Miocene period, the integrity of many cones and craters not opposing any sound objection to the opinion that they may be of very great antiquity.

3rdly. There are alluviums in Auvergne of very different ages, some of them belonging to the Miocene period. Many of these have been covered by lava-currents which have been poured out in succession while the excavation of valleys was in progress.

4thly. There are a multitude of cones in Auvergne, Velay, and the Vivarais, which have never been sub-

jected to the action of a violent rush of waters capable of modifying considerably the surface of the earth.

5thly. If, therefore, the Mosaic deluge be represented as universal, and as having exercised a violent denuding force, all these cones, several hundred in number, must be post-diluvian.

6thly. But since the beginning of the historical era, or the invasion of Gaul by Julius Cæsar, the volcanic action in Auvergne has been dormant; and there is nothing to countenance the idea that, between the date usually assigned to the Mosaic deluge and the earliest traditional and historical records of Central France (a period of little more than twenty centuries), all or any one of the more entire cones of loose scoriæ were thrown up.

Lastly. It is the opinion of some writers, that the earth's surface underwent no great modification at the era of the Mosaic deluge, and that the strictest interpretation of the Scriptural narrative does not warrant us in expecting to find any geological monuments of the catastrophe; an opinion which would be consistent with the preservation of these volcanic cones, however high their antiquity.

CHAPTER XX.

EOCENE FORMATIONS — *continued.*

Basin of the Cotentin, or Valognes — Rennes — Basin of the Netherlands — Aix, in Provence — Fossil insects — Vicentine — Tertiary strata of England — Basins of London and Hampshire — Different groups — Plastic clay and sand — London clay (p. 227.)— Bagshot sand — Fresh-water strata of the Isle of Wight— Palæotherium and other fossils of Binstead — English Eocene strata conformable to chalk — Outliers on the elevated parts of the chalk (p. 231.).

In addition to the Eocene formations treated of in the last three chapters, there are others in the north of Europe, the geographical position of which is delineated on the annexed map.*

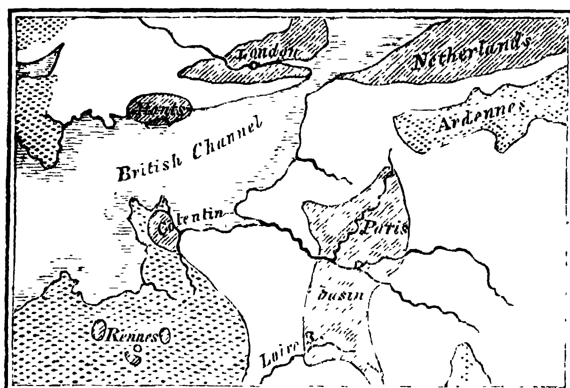
Basin of the Cotentin, or Valognes. — The strata in the environs of Valognes, in the department of La Manche, consist chiefly of a coarse limestone resembling the calcaire grossier of Paris, of which M. Desnoyers has given an elaborate description. It is occasionally covered with a compact fresh-water limestone alternating with fresh-water marls. In these Eocene strata more than 300 species of fossil shells have been discovered, almost all identical with species of the

* This map is copied from one given by M. Desnoyers, Mém. de la Soc. d'Hist. Nat. de Paris, 1825, pl. 9.; compiled partly from that author's observations, and partly from Mr. Webster's map, Geol. Trans., 1st series, vol. ii. plate 10.

Paris basin. Superimposed upon the Eocene strata of this basin is a newer marine deposit, extending over a

MAP OF THE PRINCIPAL TERTIARY BASINS OF THE EOCENE PERIOD.

Fig. 132.



Primary rocks and strata older than the carboniferous series. Eocene formations.

N. B. The space left blank is occupied by secondary formations, from the old red sandstone to the chalk inclusive.

limited area, the fossils of which agree with those of the faluns of the Loire.* Here, therefore, the geologist has an opportunity of observing the superposition of the Miocene deposits upon those of the age of the Paris basin.

Rennes. — Several small patches, also, of marine strata, have been found by M. Desnoyers, in the neighbourhood of Rennes, which are characterized by Eocene fossils and repose on ancient rocks, as will be seen in the map.

* Desnoyers, Mém. de la Soc. d'Hist. Nat. de Paris, 1825.

Basin of Belgium, or the Netherlands.—The greater part of the tertiary formations of the Low Countries consist of clay and sand, much resembling those of the basin of London, afterwards to be described; and the fossil shells are of the same species.

Aix in Provence.—The tertiary strata of Aix and Fuveau, in Provence, are of great thickness and extent. the lower members being remarkable for containing coal grit and beds of compact limestone, such as in England are found only in ancient secondary groups. Yet these strata are for the most part of fresh-water origin, and contain several species of Eocene shells, together with many which are peculiar to this basin. It will require a fuller comparison than has yet been made of the fossil remains of Aix and Fuveau, before we can determine with accuracy the relative age of this formation. Some of the plants seem to agree with those of the Paris basin, while many of the insects have been supposed identical with species now living.* These insects have been almost exclusively procured from a thin bed of grey calcareous marl, which passes into an argillaceous limestone found in the quarries of gypsum near Aix. The rock in which they are imbedded is so thinly laminated, that there are sometimes more than seventy layers in the thickness of an inch. The insects are for the most part in an extraordinary state of preservation, and an impression of their form is seen both on the upper and under laminæ, as in the case of the Monte Bolca fishes. M. Marcel de Serres enumerates sixty-two genera, belonging chiefly to the orders Diptera, Hemiptera, and Coleoptera. On re-

* M. Marcel de Serres, Géog. des Ter. Tertiaires du Midi de la France.

viewing a collection brought from Aix, Mr. Curtis observes that they are all of European forms, and most of them referrible to existing genera.* With the single exception of an Hydrobius, none of the species are aquatic. The antennæ, tarsi, and trophi are generally very obscure, or distorted; yet in a few the claws are visible, and the sculpture, and even some degree of local colouring, are preserved. The nerves of the wings, in almost all the Diptera, are perfectly distinct, and even the pubescence on the head of one of them. Several of the beetles have the wings extended beyond the elytra, as if they had made an effort to escape by flying, or had fallen into the water while on the wing.†

Vicentine.—On the Southern flank of the Alps to the north of Vicenza, in Italy, a limestone occurs containing shells of Eocene species, and in the basaltic tuffs associated with this limestone (as at Ronca and other places) shells are found which are also identical with species of the Paris basin.‡

Basins of London and Hampshire.

The reader will see in the small map above given (Fig. 132. p. 222.), the position of the two districts usually called the basins of London and Hampshire, to which the Eocene formations of England are confined. These tracts are bounded by rising grounds composed of chalk, except where the sea intervenes. That the chalk passes beneath the tertiary strata, we can not only infer from geological data, but can prove by numerous artificial sections at points where wells

* Murchison and Lyell. Ed. New Phil. Journ., Oct. 1829.

† Curtis, ibid., where figures of some of the insects are given.

‡ See list of species collected by M. Boué, and named by M. Deshayes, Bull. de la Soc. Géol. de France, tom. iii. p. 91.

have been sunk, or borings made through the overlying beds. The Eocene deposits are chiefly marine, and have generally been divided into three groups: 1st, the Plastic clay and sand, which is the lowest group; 2dly, the London clay; and, 3dly, the Bagshot sand. Of all these the mineral composition is very simple; for they consist almost entirely of clay, sand, and shingle, the great mass of clay being in the middle, and the upper and lower members of the series being more arenaceous.

Plastic clay and sand.—The lowest formation, which sometimes attains a thickness of from four hundred to five hundred feet, consists principally of an indefinite number of beds of sand, shingle, clay, and loam, irregularly alternating, some of the clay being used in potteries, in reference to which the name of Plastic clay has been given to the whole formation. The beds of shingle are composed of perfectly rolled chalk flints, with here and there small pebbles of quartz. Heaps of these materials appear sometimes to have remained for a long time covered by a tranquil sea. Dr. Buckland mentions that he observed a large pebble in part of this formation at Bromley, to which five full-grown oyster-shells were affixed, in such a manner as to show that they had commenced their first growth upon it, and remained attached through life.*

In some of the associated clays and sand, perfect marine shells are met with, which are of the same species as those of the London clay. The line of separation, indeed, between this superincumbent blue clay and the Plastic clay and sand is quite arbitrary, as any geologist may be convinced who examines the

* Geol. Trans., First Series, vol. iv. p. 300.

celebrated section in Alum Bay, in the Isle of Wight, where a distinct alternation of the two groups is observable, each marked with their most characteristic peculiarities.* In the midst of the sands of the lower series a mass of clay occurs two hundred feet thick, containing septaria, and replete with the usual fossils of the neighbourhood of London.†

The *arenaceous* beds are chiefly laid open on the confines of the basins of London and Hampshire, in following which we discover at many places great beds of perfectly rounded flints. Of this description, on the southern borders of the basin of London, are the hills of Comb Hurst and the Addington hills, which form a ridge stretching from Blackheath to Croydon. Here they have much the appearance of banks of sand and shingle formed near the shores of a tertiary sea; but whether they were really of littoral origin cannot be determined, for want of a sufficient number of sections, which might enable us to compare the tertiary strata at the edges with those in the central parts of each basin.

We have ample opportunities in the basin of Paris of examining steep cliffs of hard rock, which bound many of the valleys, and innumerable excavations have been made for building-stone, limestone, and gypsum; but when we attempt to obtain a connected view of any considerable part of the tertiary series in the basin of London, we are almost entirely limited to a single line of coast-section; for in the interior

* See Mr. Webster's Memoir, Geol. Trans., vol. ii., First Series, and his Letters in Sir H. Englefield's Isle of Wight.

† See Mr. Webster's Sections, plate 11. Geol. Trans., vol. ii., First Series.

the regular beds are much concealed by an alluvial covering of flint gravel spread alike over the summits and gentle slopes of the hills, and over the bottoms of the valleys.

Organic remains are extremely scarce in the Plastic clay; but when any shells occur they are of Eocene species. Vegetable impressions and fossil wood are sometimes met with, and even beds of lignite; but none of the *species* of plants have, I believe, as yet been ascertained.

London clay. — This formation consists of a bluish or blackish clay, sometimes passing into a calcareous marl, rarely into a solid rock. Its thickness is very great, sometimes exceeding five hundred feet.* It contains many layers of ovate or flattish masses of argillaceous limestone, which, in their interior, are generally traversed in various directions by cracks, partially or wholly filled by calcareous spar. These masses, called septaria, are sometimes continued through a thickness of two hundred feet.†

A great number of the marine shells of this clay have been identified with those of the Paris basin; and it is quite evident that the strata of these two basins belong to the same epoch.

No remains of terrestrial mammalia have as yet been found in this clay; but the occurrence of bones and skeletons of crocodiles and turtles prove, as Mr. Conybeare justly remarks, the existence of neighbouring dry land. The shores, at least, of some islands were accessible, whither these creatures may have resorted to lay their eggs. In like manner, we may infer the con-

* Con. and Phil. Outlines of Geol., p. 33.

† Outlines of Geol., p. 27.

tiguity of land from the immense number of ligneous seed-vessels of plants, some of them resembling the cocoa-nut, and other spices of tropical regions, which have been found fossil in great profusion in the Isle of Sheppey. Such is the abundance of these fruits, that they have been supposed to belong to several hundred distinct species of plants.

Bagshot sand. — The third and uppermost group, usually termed the Bagshot sand, rests conformably upon the London clay, and consists of siliceous sand and sandstone devoid of organic remains, with some thin deposits of marl associated. From these *marls* a few marine shells have been obtained which are in an imperfect state, but appear to belong to Eocene species common to the Paris basin.*

Fresh-water strata of the Hampshire basin. — In the northern part of the Isle of Wight, and part of the opposite coast of Hampshire, fresh-water strata occur resting on the London clay. They are composed chiefly of calcareous and argillaceous marls, interstratified with some thick beds of siliceous sand, and a few layers of limestone sometimes slightly siliceous. The marls are often green, and bear a considerable resemblance to the green marls of Auvergne and the Paris basin. The shells and gyrogonites also agree specifically with some of those most common in the French deposits. Mr. Webster, who first described the fresh-water formation of Hampshire, divided it into an upper and lower series, separated by intervening beds of marine origin. There are undoubtedly certain intercalated strata, both in the Isle of Wight and coast of Hampshire, marked by a slight inter-

* Warburton, Geol. Trans., vol. i., Second Series.

mixture of marine and fresh-water shells, sufficient to imply a temporary return of the sea, before and after which the waters of a lake, or rather, perhaps, some large river, prevailed. * The united thickness of the fresh-water and intercalated upper marine beds, exposed in a vertical precipice in Headen Hill, in the Isle of Wight, is about four hundred feet, the marine series appearing about half way up in the cliff.

Eocene mammiferous remains. — Very perfect remains of tortoises and the teeth of crocodiles have been procured from the fresh-water strata; but a still more interesting discovery has recently been made. The bones of mammalia, corresponding to those of the celebrated gypsum of Paris, have been disinterred at Binstead, near Ryde, in the Isle of Wight. In the ancient quarries near this town a limestone, belonging to the lower fresh-water formation, is worked for building. Solid beds alternate with marls, wherein a tooth of an Anoplotherium, and two teeth of the genus Palæotherium, were found. These remains were accompanied not only by several other fragments of the bones of Pachydermata (chiefly in a rolled and injured state), but also by the jaw of a new species of Ruminantia, apparently closely allied to the genus Moschus. † Mr. T. Allan of Edinburgh had several years before found the tooth of an Anoplotherium at the same spot.

These newer strata of the Isle of Wight bear a certain degree of resemblance to some of the green

* See Memoirs of Mr. Webster, Geol. Trans., vol. ii., First Series; vol. i. part i., Second Series; and Englefield's Isle of Wight. — Professor Sedgwick, Ann. of Phil., 1822; and Lyell, Geol. Trans. vol. ii., Second Series.

† Pratt, Proceedings of Geol. Soc., No. 18. p. 239.

marls and limestones in the Paris basin; yet, as a whole, no formations can be more dissimilar in mineral character than the Eocene deposits of England and Paris. In our own island the tertiary strata are more exclusively marine; and it might be said that the Parisian series differs chiefly from that of London in the very points in which it agrees with the formations of Auvergne, Cantal, and Velay. The tertiary formations of England are, in fact, almost exclusively of mechanical origin, and their composition bespeaks the absence of those mineral and thermal waters to which I have attributed the origin of the compact and siliceous limestones, the gypsum, and beds of pure flint. common to the Paris basin and Central France.

English tertiary strata conformable to the chalk.— The British Eocene strata are nearly conformable to the chalk on which they rest, being horizontal where the strata of the chalk are horizontal, and vertical where they are vertical. On the other hand, there are evident signs that the surface of the chalk had, in many places, been furrowed by the action of the waves and currents, before the Plastic clay and its sands were superimposed. In the quarries near Rochester and Gravesend, for instance, fine examples are seen of deep indentations on the surface of the chalk, into which sand, together with rolled and angular pieces of chalk-flint, have been swept.* But these appearances may be referred to the action of water when the chalk began to emerge during the Eocene period, and they by no means warrant the conclusion that the chalk had undergone any con-

* Con. and Phil., Outlines of Geol., p. 62.

siderable change of position before the tertiary strata were superimposed.

In this respect there is a marked difference between the reciprocal relations of our secondary and tertiary rocks and those which exist between the same groups throughout the greater part of the Continent, especially in the neighbourhood of mountain-chains. Near the base, for example, of the Alps, Apennines, and Pyrenees, we find the newer formations reposing unconformably upon the truncated edges of the older beds; and it is clear that, in many cases, the older strata had been subjected to a complicated series of movements before the more modern set was formed. The newer beds rise only to a certain height on the flanks of the mountains which usually tower above them, and are recognized at once by the geologist as having been already converted into land when the tertiary deposits were still forming in the sea. The ancient borders also of that sea can often be defined with certainty, and the outline of some of its bays and sea-cliffs traced.

In England, although undoubtedly the greater portion of the tertiary strata is confined to certain spaces, we find outlying patches here and there at great distances beyond the general limits, and at great heights upon the chalk which separates the basins of London and Hampshire.* I have seen masses of clay extending in this manner to near the edge of the western escarpment of the chalk of Wiltshire, and Mr. Mantell has pointed out the same to me in the South Downs. Near the escarpment at Lewes, for example, there is a fissure in the chalk filled with sand, and with a fer-

* Dr. Buckland, Geol. Trans., Second Series, vol. ii. p. 125.

ruginous breccia, such as usually marks the lower members of the Plastic clay formation. From the occurrence of these tertiary outliers Dr. Buckland inferred, "that the basins of London and Hants were originally united together in one continuous deposit across the now intervening chalk of Salisbury Plain in Wilts, and the plains of Andover and Basingstoke in Hants; and that the greater integrity in which the tertiary strata are preserved within the basins has resulted from the protection which their comparatively low position has afforded them from the ravages of diluvial denudation." *

I agree so far with this conclusion as to believe that the basins of London and Hampshire were not separated until part of the tertiary strata were deposited; but I do not think it probable that the tertiary beds ever extended continuously over those spaces where the outliers above mentioned occur, nor that the comparative thinness of those deposits in the higher chalk countries should be attributed chiefly to the greater degree of denudation which they have there suffered.

* Dr. Buckland, Geol. Trans., Second Series, vol. ii. p. 126.

CHAPTER XXI.

ORIGIN OF THE ENGLISH EOCENE FORMATIONS AND DENUDATION OF THE WEALD.

Manner in which the English tertiary strata may have originated — Denudation of secondary strata during their deposition — Valley of the Weald — Secondary rocks of the Weald divisible into five groups — North and South Downs — Section across the valley of the Weald — Anticlinal axis — Chalk escarpments once sea-cliffs (p. 239.) — Rise and denudation of the strata gradual — Parallel ridges and valleys formed by harder and softer beds — No ruins of the chalk on the central district of the Weald (p. 247.) — Double system of valleys, the longitudinal and the transverse (p. 250.)

Preliminary views.—In explanation of the phenomena described in the last chapter, I shall now endeavour to lay before the reader a view of the series of events which may have produced the leading geological and geographical features of the south-east of England. I conceive that the chalk, together with many subjacent rocks, may have remained undisturbed and in horizontal stratification until after the commencement of the Eocene period. When at length the chalk was upheaved and exposed to the action of the waves and currents, it was rent and shattered, so that the subjacent secondary strata were soon after exposed to denudation. The waste of all these rocks, composed chiefly of sandstone and clay, supplied materials for the tertiary

sands and clays; while the chalk was the source of flinty shingle, and of the calcareous matter which we find intermixed with the Eocene clays. The tracts now separating the basins of London and Hampshire were those first elevated, and which contributed by their gradual decay to the production of the newer strata. These last were accumulated in deep submarine hollows, formed probably by the subsidence of certain parts of the chalk, which sank while the adjoining tracts were rising.

Denudation of the Valley of the Weald.—In order to understand this theory, it will be necessary that the reader should be acquainted with the phenomena of denudation exhibited by the chalk and some of the older secondary rocks in parts of England, most nearly contiguous to the basins of London and Hampshire. It will be sufficient to consider one of the denuded districts, as the appearances observable in others are strictly analogous; I shall, therefore, direct attention to what may be called *the Valley of the Weald*, or the region intervening between the North and South Downs.

Map. — The district alluded to is delineated in the coloured map, given in Plate XV., which has been chiefly taken from Mr. Greenough's Map of England; and it will be there seen that the southern portion of the basin of London, and the north-eastern limits of that of Hampshire, are separated by a tract of secondary rocks, between forty and fifty miles in breadth, comprising within it the whole of Sussex, and parts of the counties of Kent, Surrey, and Hampshire.

There can be no doubt that the tertiary deposits of the Hampshire basin formerly extended much farther along our southern coast towards Beachey Head, for

patches are still found near Newhaven, and at other points, as will be seen by the map. These are now wasting away, and will in time disappear, as the sea is constantly encroaching and undermining the subjacent chalk.

The secondary rocks, depicted on the map, may be divided into five groups: —

1. *Chalk and Upper green-sand.* — This group is the uppermost of the series; it includes the white chalk with and without flints, and an inferior deposit, called, provincially, "Firestone," and by English geologists, the "Upper green-sand." It sometimes consists of loose siliceous sand, containing grains of silicate of iron, but often of firm beds of sandstone and chert.
2. Blue clay or calcareous marl, called, provincially, *Gault.*
3. *Lower green-sand*, a very complex group, consisting of grey, yellowish, and greenish sands; ferruginous sand and sandstone; clay, chert, and siliceous limestone.
4. *Weald clay*, composed for the most part of clay without intermixture of calcareous matter, but sometimes including thin beds of sand and shelly limestone.
5. *Hastings sands*, composed chiefly of sand, sandstone, clay, and calcareous grit, passing into limestone.*

The first three formations above enumerated are of marine origin; the last two, Nos. 4. and 5., contain

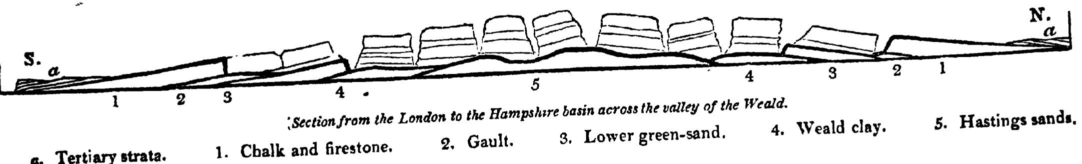
* For an account of these strata in the south-east of England, see Mantell's Geology of Sussex, and Dr. Fitton's Geology of Hastings, where the memoirs of all the writers on this part of England are referred to.

almost exclusively the remains of fresh-water and amphibious animals. But it is not my intention to enlarge, at present, upon the organic remains of these formations, as the rocks are merely adverted to, in order that I may describe the changes of position which they have undergone, and the denudation to which they have been exposed since the commencement of the Eocene period,—mutations which, if the theory about to be explained be well founded, belong strictly to the history of *tertiary* phenomena.

By a glance at the map, the reader may trace at once the superficial area occupied by each of the five formations above mentioned. On the west will be seen a large expanse of chalk, from which two branches are sent off; one through the hills of Surrey and Kent to Dover, forming the ridge called the North Downs; and the other through Sussex to the sea at Beachy Head, constituting the South Downs. The space comprised between the North and South Downs, or, "the Valley of the Weald," consists of the formations Nos. 2, 3, 4, 5, of the above table. It will be observed that the chalk terminates abruptly, and with a well-defined line towards the country occupied by those older strata. Within that line is a narrow band, coloured blue, formed by the gault; and within this again, is the Lower green-sand, next the Weald clay; and then, in the centre of the district, a ridge formed by the Hastings sands.

Section of the Valley of the Weald.—It has been ascertained, by careful investigation, that if a line be drawn from any part of the North to the South Downs, which shall pass through the central group (No. 5.), the beds will be found arranged in the order described in the annexed section (Fig. 133.).

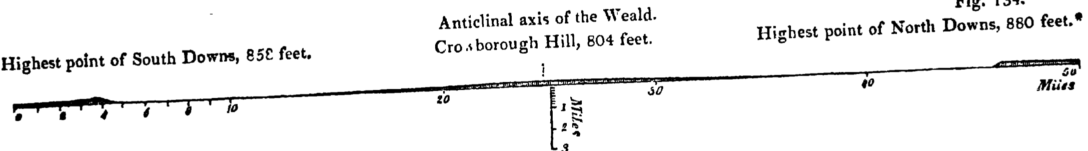
Fig. 133.



Section from the London to the Hampshire basin across the valley of the Weald.

a. Tertiary strata. 1. Chalk and firestone. 2. Gault. 3. Lower green-sand. 4. Weald clay. 5. Hastings sands.

Fig. 134.



Section of the country from the confines of the basin of London to that of Hants, with the principal heights above the level of the sea on a true scale.†

* Lieutenant H. Murphy, R. E., informs me that Botley Hill, near Godstone, in Surrey, was found by trigonometrical measurement to be 880 feet above the level of the sea; and Wrotham Hill, near Maidstone, which appears to be next in height of the North Downs, 795 feet.

† My friend Mr. Mantell, of Lewes, has kindly drawn up this scale at my request.

The reader is referred at present to the dark lines of the section, as the fainter lines represent portions of rock supposed to have been carried away by denudation.

At each end of the diagram the tertiary strata, *a*, are exhibited reposing on the chalk. In the centre are seen the Hastings sands (No. 5.), forming an anticlinal axis, on each side of which the other formations are arranged with an opposite dip. It has been necessary, however, in order to give a clear view of the different formations, to exaggerate the proportional height of each in comparison to its horizontal extent; and a true scale is therefore subjoined in another diagram (Fig. 134.), in order to correct the erroneous impression which might otherwise be made on the reader's mind. In this section the distance between the North and South Downs is represented to exceed forty miles; for the valley of the Weald is here intersected in its longest diameter, in the direction of a line between Lewes and Maidstone.

In attempting to account for the manner in which the five secondary groups above mentioned may have been brought into their present position, the following hypothesis has been very generally adopted:—Suppose the five formations to lie in horizontal stratification at the bottom of the sea; then let a movement from below press them upwards into the form of a flattened dome, and let the crown of this dome be afterwards cut off, so that the incision should penetrate to the lowest of the five groups. The different beds would then be exposed on the surface, in the manner exhibited in the map, Pl. XV.*

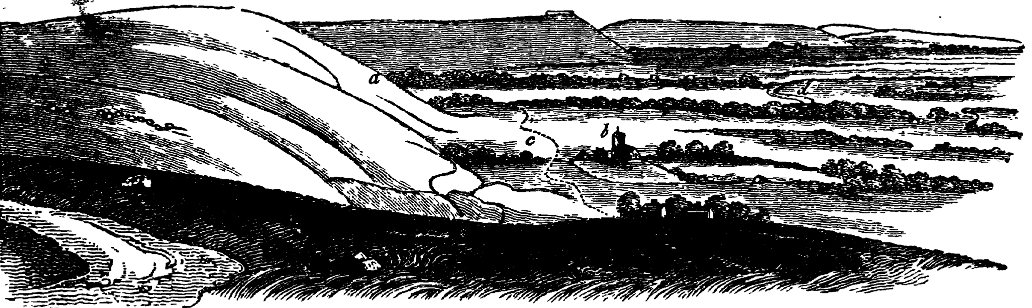
* See illustrations of this theory by Dr. Fitton, Geol. Sketch of Hastings.

It will appear, from former parts of this work, that the amount of elevation here supposed to have taken place is not greater than we can prove to have occurred in other regions within geological periods of no great duration. On the other hand, the quantity of denudation or removal by water of vast masses which are assumed to have once reached continuously from the North to the South Downs is so enormous, that the reader may at first be startled by the boldness of the hypothesis. But he will find the difficulty to vanish when once sufficient time is allowed for the gradual and successive rise of the strata, during which the waves and currents of the ocean might slowly accomplish an operation, which no sudden diluvial rush of waters could possibly have effected.

Escarpments of the chalk once sea-cliffs.—In order to make the reader acquainted with the physical structure of the Valley of the Weald, I shall suppose him first to travel southwards from the London basin. On leaving the tertiary strata he will first ascend a gently inclined plane, composed of the upper flinty portion of the chalk, and then find himself on the summit of a declivity consisting, for the most part, of different members of the chalk formation; below which the upper green-sand, and sometimes also the gault, *crop out.** This steep declivity is called by geologists "the escarpment of the chalk," which overhangs a valley excavated chiefly out of the argillaceous or marly bed, termed Gault (No. 2.). The escarpment is continuous along the southern termination of the North Downs, and may be traced from the sea at Folkstone, west-

* This term, borrowed from our miners, is used to express the coming up to the surface of one stratum from beneath another.

Fig. 135.



View of the chalk escarpment of the South Downs. Taken from the Devil's Dike, looking towards the west and south-west.

a. The town of Steyning is hidden by this point. *b*. Edburton church. *c*. Road. *d*. River Adur.

ward to Guildford and the neighbourhood of Petersfield, and from thence to the termination of the South Downs at Beachy Head. In this precipice or steep slope the strata are cut off abruptly, and it is evident that they must originally have extended farther. In the accompanying wood-cut (Fig 135.), part of the escarpment of the South Downs is faithfully represented, where the denudation at the base of the declivity has been somewhat more extensive than usual, in consequence of the upper and lower green-sand being formed of very incoherent materials, the upper, indeed, being extremely thin and almost wanting.

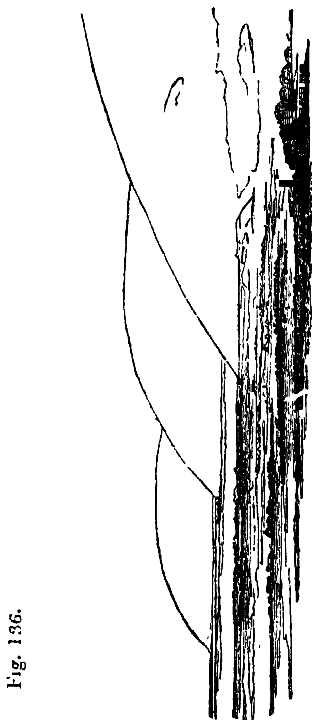


Fig. 136.

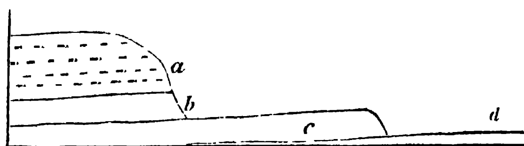
Chalk escarpment as seen from the hill above Steyning, Sussex. The castle and village of Bramber in the foreground.

The geologist cannot fail to recognize in this view the exact likeness of a sea-cliff; and if he turns and looks in an opposite direction, or eastward, towards Beachy Head (see Fig. 136.), he will see the same line of height prolonged. Even those who are not accustomed to speculate on the former changes which the

surface has undergone may fancy the broad and level plain to resemble the flat sands which were laid dry by the receding tide, and the different projecting masses of chalk to be the headlands of a coast which separated the different bays from each other.

Lower terrace of firestone.—I have said that the upper green-sand ("firestone," or "malm-rock," as it is sometimes called) is almost absent in the tract here alluded to. It is, in fact, seen at Beachy Head to thin out to an inconsiderable stratum of loose green-sand; but farther to the westward it is of great thickness, and contains hard beds of blue chert and limestone. Here, accordingly, we find that it produces a corresponding influence on the scenery of the country; for it runs out like a step beyond the foot of the chalk-hills, and constitutes a lower terrace, varying in breadth from a quarter of a mile to three miles, and following the sinuosities of the chalk escarpment.*

Fig. 137.



a. Chalk with flints. b. Chalk without flints.
c. Upper green-sand, or firestone. d. Gault.

It is impossible to desire a more satisfactory proof that the escarpment is due to the excavating power of water during the rise of the strata; for I have shown, in my account of the coast of Sicily, in what manner the encroachments of the sea tend to efface that suc-

* Mr. Murchison, Geol. Sketch of Sussex, &c., Geol. Trans., Second Series, vol. ii. p. 98.

cession of terraces which must otherwise result from the successive rises of a coast preyed upon by the waves.* During the interval between two elevatory movements, the lower terrace will usually be destroyed, wherever it is composed of incoherent materials; whereas the sea will not have time entirely to sweep away another part of the same terrace, or lower platform, which happens to be composed of rocks of a harder texture, and capable of offering a firmer resistance to the erosive action of water.

Valleys where softer strata, ridges where harder crop out.—It is evident that the gault No. 2. (see the map) could not have opposed any effectual resistance to the denuding force of the waves; its outcrop, therefore, is marked by a valley, the breadth of which is often increased by the loose incoherent nature of the uppermost beds of the lower green-sand, which lie next to it, and which have often been removed with equal facility.

This formation (the lower green-sand) has been sometimes entirely smoothed off like the gault; but in those districts where chert, limestone, and other solid materials enter largely into its composition, it forms a range of hills parallel to the chalk, which sometimes rival the escarpment of the chalk itself in height, or even surpass it, as in Leith Hill. This ridge often presents a steep escarpment towards the Weald clay which crops out from under it. (See the strong lines in Fig. 133. p. 237.)

The clay last mentioned forms, for the most part, a broad valley, separating the lower green-sand from the Hastings sands, or Forest ridge; but where subordinate

* See p. 8. and wood-cut No. 87.

beds of sandstone of a firmer texture occur, the uniformity of the plain is broken by waving irregularities and hillocks.*

In the central region, or Forest ridge, the strata have been considerably disturbed, and are greatly fractured and shifted. One fault is known where the vertical shift of a bed of calcareous grit is no less than sixty fathoms. † It must not be supposed that the anticlinal axis, which is described as running through the centre of the Weald, is by any means so simple as is usually represented in geological sections. There are, on the contrary, a series of anticlinal and synclinal ‡ lines, which form ridges and troughs running nearly parallel to each other.

Much of the picturesque character of the scenery of this district arises from the depth of the narrow valleys and ridges to which the sharp bends and fractures of the strata have given rise; but it is also in part to be attributed to the excavating power exerted by water, especially on the interstratified argillaceous beds.

From the above description it will appear that, in the tract intervening between the North and South Downs, there are a series of parallel valleys and ridges; the valleys appearing evidently to have been formed principally by the removal of softer materials, while the ridges are due to the resistance offered by firmer beds to the destroying action of water.

Rise and denudation of the strata gradual. — Let us then consider how far these phenomena agree with the

* Martin, Geol. of Western Sussex. Fitton, Geol. of Hastings, p. 31.

† Fitton, Ibid. p. 55.

‡ For explanation of these terms, see Glossary, Vol. I.

changes which we should naturally expect to occur during the rise of the secondary strata. Suppose the line of the most violent movements to have coincided with what is now the central ridge of the Weald valley; in that case the first land which emerged must have been situated where the Forest ridge is now placed. Here a number of reefs may have existed, and islands of chalk, which may have been gradually devoured by the ocean in the same manner as Heligoland and other

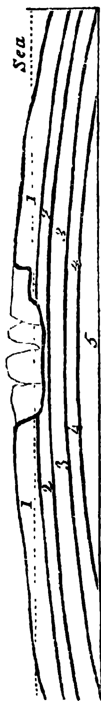


Fig. 138.

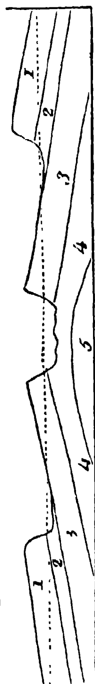


Fig. 139.

The dotted lines represent the sea-level.

European islands have disappeared in modern times, as related in the second book.*

Suppose the ridge or dome first elevated to have been so rent and shattered on its summit as to give more easy access to the waves, until at length the masses represented by the fainter lines (Fig. 138.) were removed. Two strips of land might then remain on each side of a channel, in the same manner as the opposite coasts of France and England, composed of chalk, present ranges of white cliffs facing each other. A powerful current might then rush, like that which now ebbs and flows through the Straits of Dover, and might scoop out a channel in the gault. We must bear in mind that the intermittent action of earthquakes would accompany this denuding process, fissuring rocks, throwing down cliffs, and bringing up, from time to time, new stratified masses, and thus greatly accelerating the rate of waste. If the lower bed of chalk on one side of the channel should be harder than on the other, it would cause an under terrace, as represented in the diagram (Fig. 138.), resembling that presented by the upper green-sand in parts of Sussex and Hampshire. When at length the gault was entirely swept away from the central parts of the channel, the lower green-sand (3. Fig. 139.) would be laid bare, and portions of it would become land during the continuance of the upheaving earthquakes. Meanwhile the chalk cliffs would recede farther from one another, whereby four parallel strips of land, or perhaps rows of islands, would be caused.

By a continuance of these operations the edges of the argillaceous strata, No. 2. (Fig. 139.), would be ex-

* Vol. II. p. 58.

posed to farther erosion by the waves, and a portion of the clay, No. 4., would be also removed, and as it gradually rose, would be swept off from part of the subjacent group, No. 5. This last would then in its turn be laid bare, and afterwards become land by subsequent elevation.

Why no ruins of chalk on central district. — By this theory of the successive emergence and denudation of the groups, 1, 2, 3, 4, 5., we may account for an alluvial phenomenon which seems inexplicable on any other hypothesis. The summits of the chalk downs are covered every where with flint gravel, which is often entirely wanting on the surface of the clay at the foot of the chalk escarpment, and no traces of chalk flint have ever been found in the alluvium of the central district, or Forest ridge. It is rare, indeed, to see any wreck of the chalk, even at the distance of two or three miles from the escarpments of the North and South Downs, a fact attested by those road-surveyors who have diligently sought for such materials. To this general rule, however, an exception occurs near Barcombe,

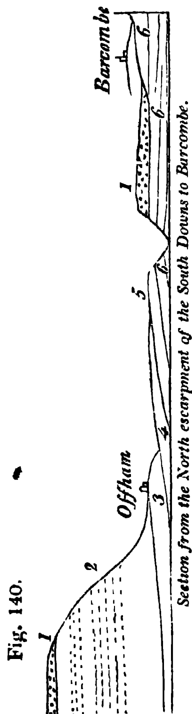


Fig. 140. *Section from the North escarpment of the South Downs to Barcombe.*

1. Gravel composed of partially rounded chalk flints.
2. Chalk with and without flints.
3. Lowest chalk or chalk marl (upper green-sand wanting).
4. Gault.
5. Lower green-sand.
6. Weald clay.

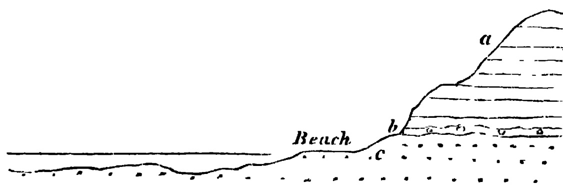
about three miles to the north of Lewes, a place which I visited with Mr. Mantell, to whom I am indebted for the accompanying section (Fig. 140.). It will be seen that the valley at the foot of the escarpment extends, in this case, not only over the gault, but over the "lower green-sand" to the Weald clay. On this clay a thick bed of flints, evidently derived from the waste of chalk, remains in the position above described.

When I say that there is no detritus of the chalk and its flints on the central ridge of the Weald, I may state that I have sought in vain for a vestige of such fragments; and Mr. Mantell, who has had greater opportunities of minute investigation, assures me that he has never been able to detect any. Now, whether we embrace or reject the theory of the former continuity of the chalk and other groups over the whole space intervening between the North and South Downs, we certainly cannot imagine that any transient and tumultuous rush of waters could have swept over this country, which should not have left some fragments of the chalk and its flints in the deep valleys of the Forest ridge. Indeed, if we adopt the diluvial hypothesis of Dr. Buckland, we should expect to find vast heaps of broken flints drifted frequently into the valleys of the Gault and Weald clay, instead of being generally confined to the summit of the chalk downs.

On the other hand, it is quite conceivable that the slow agency of oceanic currents may have cleared away, in the course of ages, the matter which fell into the sea from wasting cliffs. But in order that this explanation should be satisfactory we must suppose that the rise of the land in the south-east of England was very gradual, and the subterranean movements for the most part of moderate intensity. During the last cen-

tury earthquakes have occasionally thrown down at once whole lines of sea-cliffs, for several miles continuously; but if this had happened repeatedly during the waste of the ancient escarpments of the chalk now encircling the Weald, and if the shocks had been accompanied by the sudden rise and conversion of large districts into land, the Weald would have been covered with the ruins of those wasted rocks, and the sea could not possibly have had time to clear the whole away. The reader will recollect the account before given of the manner in which the sea has advanced, within the last century, upon the Norfolk coast at Sherringham.*

Fig. 141.



Section of cliffs west of Sherringham.

Crag.
b. Ferruginous flint breccia on the surface of the chalk.
c. Chalk with flints.

The beach, at the foot of the cliff, is composed of bare chalk with flints, as is the bed of the sea near the shore. No one would suspect, from the appearance of the beach at low water, that a few years ago beds of solid chalk, together with sand and loam of the superincumbent crag, formed land on the very spot where the waves are now rolling; still less that these

* Vol. II. p. 25.

same formations extended, within the last fifty years, to a considerable distance from the present shore, over a space where the sea has now excavated a channel twenty feet deep.

As in this recent instance the ocean has cleared away part of the chalk, and its capping of crag, so the tertiary sea may have swept away not only the chalk surrounding the valley of the Weald, but the layer of broken flints on its surface, which was probably a marine alluvium of the Eocene period. Hence these flints might naturally occur on the downs, and be wanting in the valleys below.

If the reader will refer to the preceding diagrams (Figs. 138. and 139. p. 245.), and reflect not only on the successive states of the country there delineated, but on all the intermediate conditions which the district must have passed through during the process of gradual elevation and denudation before supposed, he will understand why no wreck of the chalk (No. 1.) should occur at great distances from the chalk escarpments; for it is evident that when the ruins of the uppermost bed (No. 1. Fig. 138.) had been thrown down upon the surface of the bed immediately below, those ruins would subsequently be carried away when this inferior stratum itself was destroyed. And in proportion to the number and thickness of the groups, thus removed in succession, is the probability lessened of our finding any remnants of the highest group strewed over the bared surface of the lowest.

Transverse valleys.—There is another peculiarity in the geographical features of the south-east of England, which must not be overlooked when we are considering the action of the denuding causes. By reference to the map (Plate XV.), the reader will perceive that

the drainage of the country is not effected by water-courses following the great valleys excavated out of the argillaceous strata (Nos. 2. and 4.), but by valleys which run in a transverse direction, passing through the chalk to the basin of the Thames on the one side, and to the English Channel on the other.

In this manner the chain of the North Downs is broken by the rivers Wey, Mole, Darent, Medway, and Stour; the South Downs by the Arun, Adur, Ouse and Cuckmere.*

If these transverse hollows could be filled up, all the rivers, observes Mr. Conybeare, would be forced to take an easterly course, and to empty themselves into the sea by Romney Marsh and Pevensey levels.†

Mr. Martin has suggested that the great cross fractures of the chalk, which have become river channels, have a remarkable correspondence on each side of the valley of the Weald; in several instances the gorges in the North and South Downs appearing to be directly opposed to each other. Thus, for example, the defiles of the Wey, in the North Downs, and of the Arun in the South, seem to coincide in direction; and, in like manner, the Ouse corresponds to the Darent, and the Cuckmere to the Medway.‡

Although these coincidences may, perhaps, be accidental, it is by no means improbable, as hinted by the author above mentioned, that the great amount of elevation towards the centre of the Weald district gave rise to transverse fissures. And as the longitudinal valleys were connected with that linear movement which caused the anticlinal lines running east and west, so

* Conybeare, Outlines of Geol., p. 81. † Ibid., p. 145.

‡ Geol. of Western Sussex, p. 61.

Fig. 142.



Transverse Valley of the Adur in the South Downs.

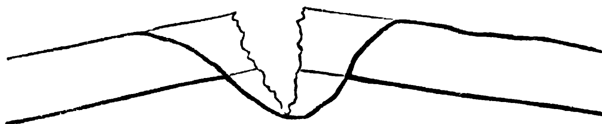
a. Town of Steyning. b. River Adur. c. Old Shoreham.

the cross fissures might have been occasioned by the intensity of the upheaving force towards the centre of the line, whereby the effect of a double axis of elevation was in some measure produced.

In order to give a clearer idea of the manner in which the chalk-hills are intersected by these transverse valleys, I subjoin a sketch (Fig. 142.) of the gorge of the river Adur, taken from the summit of the chalk downs, at a point in the bridle-way leading from the towns of Bramber and Steyning to Shoreham. If the reader will refer again to the view given in a former wood-cut (Fig. 135. p. 240.), he will there see the exact point where the gorge, of which I am now speaking, interrupts the chalk escarpment. A projecting hill, at the point *a*, hides the town of Steyning, near which the valley commences where the Adur passes directly to the sea at Old Shoreham. The river flows through a nearly level plain, as do most of the others which intersect the hills of Surrey, Kent, and Sussex; and it is evident that these openings, so far at least as they are due to aqueous erosion, have not been produced by the rivers, many of which, like the Ouse near Lewes, have filled up arms of the sea, instead of deepening the hollows which they traverse.

In regard to the origin of the transverse ravines,

Fig. 143.



Supposed section of Transverse Valley.

there can be no doubt that they are connected with lines of fracture, and perhaps, in some places, there

may be an anticlinal dip on both sides of the valley, as suggested by Mr. Martin.* But this notion requires confirmation.

The ravine, called the Coomb, near Lewes, affords a beautiful example of the manner in which narrow

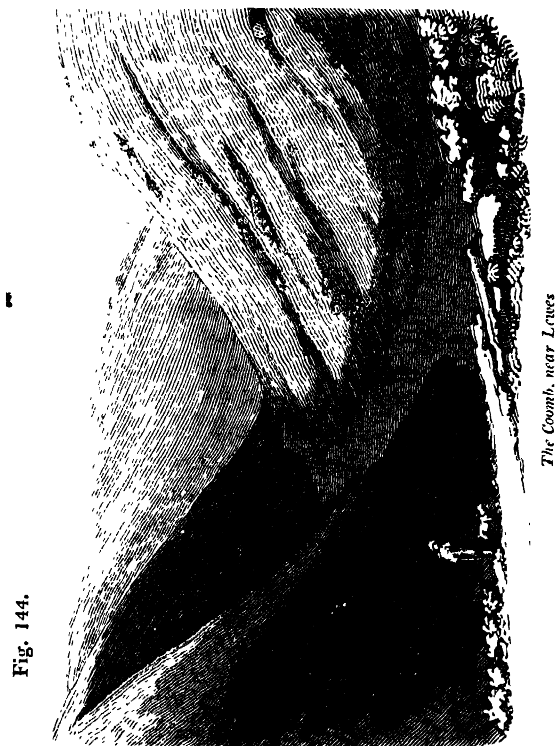


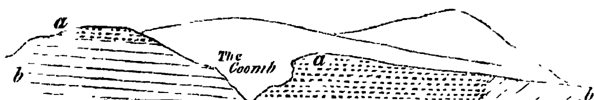
Fig. 144. The Coomb, near Lewes

openings in the chalk may have been connected with shifts and dislocations in the strata. This coomb is

* Geol. of Western Sussex, p. 64. Plate III. fig. 3.

seen on the eastern side of the valley of the Ouse, in the suburbs of the town of Lewes. The steep declivities on each side are covered with green turf, as is the bottom, which is perfectly dry. No outward signs of disturbance are visible; and the connexion of the hollow with subterranean movements would not have been suspected by the geologist, had not the evidence of great convulsions been clearly exposed in the escarpment of the valley of the Ouse, and in the numerous chalk pits worked at the termination of the Coomb. By aid of these we discover that the ravine coincides precisely with a line of fault, on one side of which the chalk with flints, *a*, appears at the summit of a hill, while it is thrown down to the bottom on the other. I examined this spot in company with Mr. Mantell, to whom I am indebted for the accompanying section.

Fig. 145.



Fault in the cliff-hills near Lewes

a. Chalk with flints. *b*. Lower chalk.*

The fracture here alluded to is one of those which run east and west, and of which there are many in the Weald district, parallel to the central axis of the Forest ridge.

In whatever manner the transverse gorges originated, they must evidently have formed ready channels of communication between the submarine longitudinal

* For farther information, see Mantell's Geol. of S. E. of England, p. 352.

valleys and those deep parts of the sea wherein the tertiary strata may have accumulated. If the strips of land which first rose had been unbroken, and there had been no free passage through the cross fractures, the currents would not so easily have drifted away the materials detached from the wasting cliffs, and it would have been more difficult to understand how the wreck of the denuded strata could have been so entirely swept away from the base of the escarpments.

In the next chapter I shall resume the consideration of these subjects, especially the proofs of the former continuity of the chalk of the North and South Downs, and the probable connexion of the denudation of the Weald valley with the origin of the Eocene strata.

CHAPTER XXII.

ORIGIN OF THE ENGLISH EOCENE FORMATIONS AND DENUDATION OF THE WEALD — *continued.*

The alternative of the proposition that the chalk of the North and South Downs was once continuous, considered — Dr. Buckland on Valleys of Elevation (p. 259.) — If rise and denudation of secondary rocks gradual, so also the deposition of tertiary strata (p. 267.) — Composition of the latter such as would result from wreck of denuded secondary rocks — Central parts of the London and Hampshire basins nearly as high as Weald — Why — Curved and vertical strata in the Isle of Wight — Eocene alluviums (p. 276.) — Formation of valleys — Recapitulation.

Extent of denudation in the Valley of the Weald.— "It would be highly rash," observes Mr. Conybeare, speaking of the denudation of the Weald, "to assume that the chalk at any period actually covered the whole space in which the inferior strata are now exposed, although the truncated form of its escarpment evidently shows it to have once extended much farther than at present." *

I believe that few geologists who have considered the extent of country supposed to have been denuded, and who have explored the hills and valleys of the central or Forest ridge, without being able to discover the slightest vestige of chalk in the alluvium †, will fail to participate, at first, in the doubts here expressed

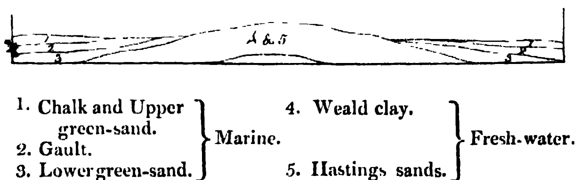
* Outlines, p. 144.

† See above, p. 247.

as to the original continuity of the upper secondary formations over the anticlinal axis of the Weald. For my own part, I never traversed the wide space which separates the North and South Downs, without desiring to escape from the conclusions advocated in the last chapter; and yet I have been invariably brought back again to the opinion, that the chalk was originally continuous, on a more deliberate review of the whole phenomena.

It may be useful to consider the only other alternative of the hypothesis before explained. If the marine groups, Nos. 1, 2, 3., were not originally con-

Fig. 146.



1. Chalk and Upper green-sand. 2. Gault. 3. Lower green-sand.	Marine.	4. Weald clay. 5. Hastings sands.	Fresh-water.

tinuous, it is necessary to imagine that they each terminated at some point between their present outgoings and the secondary strata of the Forest ridge. Thus we might suppose them to have thinned out one after the other, as in the above diagram, and never to have covered the entire area occupied by the freshwater strata, Nos. 4. and 5.

It must be granted, that had such been the original disposition of the different groups, they might, as they gradually emerged from the sea, have become denuded in the manner explained in the last chapter, so that the country might equally have assumed its present configuration. But, although I know of no invincible objection to such an hypothesis, there are certainly no

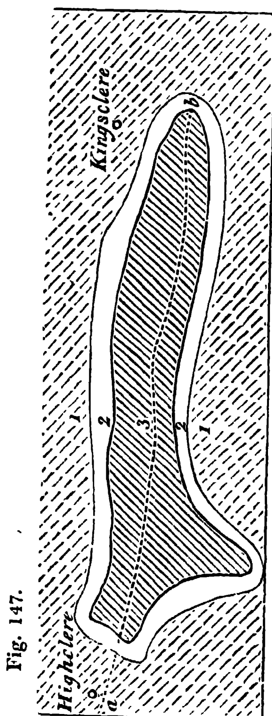
appearances which favour it. If the strata Nos. 4. and 5. had been unconformable to the lower green-sand No. 3., then, indeed, we might have imagined that the older groups had been disturbed by a series of movements antecedently to the deposition of No. 3.; and, in that case, some parts of them might be supposed to have emerged or formed shoals in the ancient sea, interrupting the continuity of the newer marine deposits. But the group No. 4. is *conformable* to No. 3.; and the only change which has been observed to take place at the junction is an occasional intermixture of the Weald clay with the superior marine sand, such as might have been caused by a slight superficial movement in the waters when the sea first overflowed the fresh-water strata.

On the other hand, the green-sand and chalk, as they approach the central axis of the Weald, are not found to contain littoral shells, or any wreck of the fresh-water strata, such as might indicate the existence of an island with its shores or wasting cliffs. Had any such signs been discovered, we might have supposed the geography of the region to have once borne some resemblance to that exhibited in the diagram Fig. 146.

Dr. Buckland on Valleys of Elevation.—We are indebted to Dr. Buckland for an able memoir in illustration of several districts of similar form and structure to the Weald, which occur at no great distance in the south of England. His paper is intitled, "On the Formation of the Valley of Kingsclere and other Valleys by the Elevation of the Strata which inclose them." *

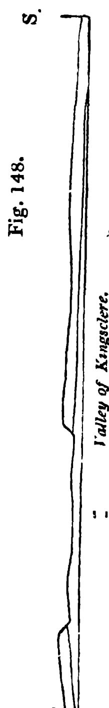
* Geol. Trans., Second Series, vol. ii. p. 119.

The valley of Kingsclere, a few miles south of Newbury, in Berkshire, is about five miles long and two in breadth. The upper and lower chalk (see Fig.* 149. *) and the upper green-sand dip in oppositedir ections from an anticlinal axis which passes through the middle of the valley along the line *a*, *b*, of the ground-plan (Fig. 147.).



Valley of Kingsclere.

a, *b*. Anticlinal line marking the junction of the opposite dip of the strata on on each side of it.



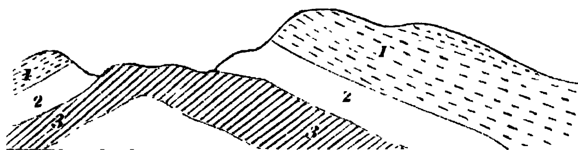
In the wood cut (Fig. 148.) the scale of heights

* Copied by permission from Dr. Buckland's Plate XVII., Geol. Trans., Second Series, vol. ii.

more nearly approaches to that of nature, although the altitudes, in proportion to the horizontal extent, are even in this, perhaps, somewhat in excess. On each side of the valley we find escarpments of chalk, the strata of which dip in opposite directions, in the northern escarpment to the north, and in the southern to the south. At the eastern and western extremities of the valley, the two escarpments become confluent, precisely in the same manner as do those of the North and South Downs, at the eastern end of the Weald district, near Petersfield. And as, a few miles east of the town last mentioned (see Map, Plate XV.), the firestone, or upper green-sand, is laid open in the sharp angle between the escarpment of the Alton Hills and the western termination of the South Downs*; so in the valley of Kingsclere the same formation is seen to crop out from beneath the chalk.

The reader might imagine, on regarding the section (Fig. 149.), where, for the sake of elucidating the geo-

Fig. 149.



Section across the Valley of Kingsclere from north to south.

1. Chalk with flints. 2. Lower chalk without flints.
3. Upper green-sand, or firestone, containing beds of chert.

N.B. The lines here are not intended to represent strata.

logical phenomena, the heights are exaggerated in proportion to the horizontal extent, that the solution of

* See Mr. Murchison's Map, Plate XIV., Geol. Trans., Second Series, vol. ii.

continuity of the strata bounding the valley of Kingsclere had been simply due to elevation and fracture, unassisted by aqueous causes; but by reference to the truer scale (Fig. 148.), it will immediately appear that a considerable mass of chalk must have been removed by denudation.

If the anticlinal dip had been confined to the valley of Kingsclere, we might have supposed that the upheaving force had acted on a mere point, forcing upwards the superincumbent strata into a small dome-shaped eminence, the crown of which had been subsequently cut off; but Dr. Buckland traced the line of opposite dip far beyond the confluence of the chalk escarpments, and found that it was prolonged in a more north-west direction far beyond the point *a* (Fig. 147.). In following the line thus extended, the strata are seen in numerous chalk-pits to have an opposite dip on either side of a central axis, from which we may clearly infer the linear direction of the movement.

Many of the valleys having a similar conformation to that of Kingsclere, run east and west, like the anticlinal ridge of the Weald valley. Several of these occur in Wiltshire and Dorsetshire, and they are all circumscribed by an escarpment whose component strata dip outwards from an anticlinal line running along the central axis of the valley. One of these, distant about seven miles to the north-east of Weymouth, is nearly elliptical in shape, and in size does not much exceed the Coliseum at Rome. Their drainage is generally effected in a manner analogous to the drainage of the Weald, by an aperture in one of their lateral escarpments, and not at either extremity of their longer

axis, as would have happened had they been simply excavated by the sweeping force of rapid water.*

"It will be seen," continues Dr. Buckland, "if we follow on Mr. Greenough's map the south-western escarpment of the chalk in the counties of Wilts and Dorset, that, at no great distance from these small elliptical valleys of elevation, there occur several longer and larger valleys, forming deep notches, as it were, in the lofty edge of the chalk. These are of similar structure to the smaller valleys we have been considering, and consist of green-sand, inclosed by chalk at one extremity, and flanked by two escarpments of the same, facing each other with an opposite dip; but they differ in the circumstance of their other and broader extremity being without any such inclosure, and gradually widening till it is lost in the expanse of the adjacent country.

"The cases I now allude to are the Vale of Pewsey, to the east of Devizes; that of the Wily, to the east of Warminster; and the Valley of the Nadder, extending from Shaftesbury to Barford, near Salisbury; in which last not only the strata of green-sand are brought to the surface, but also the still lower formations of Purbeck and Portland beds, and of Kimmeridge clay.

"It might at first sight appear that these valleys are nothing more than simple valleys of denudation; but the fact of the strata composing their escarpments having an opposite and outward dip from the axis of the valley, and this often at a high angle, as near Fonthill and Barford, in the Vale of the Nadder, and at Oare, near the base of Martinsell Hill, in the

* Dr. Buckland, Geol. Trans., Second Series, vol. ii. p. 122.

Vale of Pewsey, obliges us to refer their inclination to some antecedent violence, analogous to that to which I have attributed the position of the strata in the inclosed valleys near Kingsclere, Ham, and Burbage. Nor is it probable that, without some pre-existing fracture or opening in the lofty line of the great chalk escarpment, which is here presented to the north-west, the power of water alone would have forced open three such deep valleys as those in question, without causing them to maintain a more equable breadth, instead of narrowing till they end in a point in the body of the chalk."*

Now, in the Weald, the strata of the North Downs are inclined to the north at an angle of from 10° to 15°, or even 45°, in the narrow ridge of the Hog's Back, west of Guildford, in Surrey; while those in the South Downs dip to the south at a slight angle. It is superfluous to dwell on the analogy which, in this respect, the two escarpments bear to those which flank the valleys above alluded to; and in regard to the greater distance which separates the hills of Surrey from those of Sussex, the difficulty may be reduced simply to a question of time.

If the rise of the land was accomplished by an indefinite number of minor convulsions, or by a slow and insensible upheaving like that now taking place in Sweden, the power of the ocean would be fully adequate to perform the work of denudation in the lapse of many ages. If, on the other hand, we embrace the hypothesis of paroxysmal elevation; or, in other words, suppose a submarine tract to have been converted instantaneously into high land, we may seek in vain

* Dr. Buckland, Geol. Trans., Second Series, vol. ii. p. 123.

for any known cause capable of sweeping away even those portions of chalk and other rocks which, all are agreed, must once have formed the prolongation of the existing escarpments. It is common in such cases to call in one imaginary cause to support another; and as the upheaving force operated with sudden violence, so a vast diluvial wave is introduced to carry away, with almost equal celerity, the mountain mass of strata assumed to have been stripped off.

Some geologists have endeavoured to account for the structure of the districts described as "valleys of elevation," by the aid of Von Buch's theory of "elevation craters," in which case they can dispense both with time and denudation. It would be superfluous to repeat what has been already said of the hypothetical agency here referred to *; but it may be well to consider whether the upheaving of small dome-shaped masses, such as those described by Dr. Buckland, implies the development at a considerable depth of volcanic forces acting with great violence on limited areas, or mere points of the earth's crust.

A theory suggested by Dr. Fitton appears to me far more probable. Suppose a series of horizontal strata, composed in great part of sand and soft clay, to repose on a foundation of older and more solid rocks presenting an uneven surface, varied by hills, valleys, and ridges, like many parts of the land and bed of the sea. If a force acting from beneath should then elevate the whole mass, the protuberances of the subjacent rocks would be forced up against the more compressible strata which covered them. The effect of the pressure

* Vol. II. p. 205.

might be the same as that which happens on a small scale in a bound book, when a minute inequality or knob in the paper of some page is propagated through a great number of others, imparting its shape to all, without piercing through them.* The observations of Dolomieu on the manner in which the more yielding tertiary strata of Calabria were displaced by the granite during the earthquake of 1783, lends some countenance to this theory.†

In the last chapter I pointed out the phenomena which seem to indicate that the elevation and denudation of land in the south-east of England were gradual.‡ The same arguments are in a great degree applicable to the basins of Hampshire and the Isle of Wight; but Mr. Conybeare has contended that the verticality of the strata in the Isle of Wight and in Purbeck compels us to admit that the movement there was so violent, that the vertical strata, which have been traced through a district nearly sixty miles in length, were brought into their present position by a *single convulsion.*

It may well be asked what ground is there for assuming that a *single* effort of the subterranean force, rather than reiterated movements, produced that sharp flexure of which the verticle strata of the Isle of Wight are supposed to form a part, the remainder of the arc having been carried away by denudation?§

It is not improbable that the Cutch earthquake of 1819, before alluded to, may have produced an incipient curve, running in a linear direction through

* Dr. Fitton, Geol. Trans., Second Series, vol. iv. p. 244. 1834.

† See above, Vol. II. p. 258. ‡ Page 244.

§ See Webster, Englefield's Isle of Wight, Plate XLII. fig. 1.

a tract at least sixty miles in length.* The strata were upraised in the Ullah Bund, and depressed below the level of the sea in the adjoining tract, where the fort of Sindree was submerged. (See Plate V.) It would be impossible, if the next earthquake should raise the Bund still higher, and sink to a lower depth the adjoining tract, to discriminate, by any geological investigations, the different effects of the two earthquakes, unless a minute survey of the effects of the first shock had been made and put on record. In this manner we may suppose the strata to be bent again and again, in the course of future ages, until parts of them become perpendicular.

To some it may appear that there is a unity of effect in the line of deranged strata in the Isles of Wight and Purbeck, as also in the central axis of the Weald, which is inconsistent with the supposition of a great number of separate movements recurring after long intervals of time. But we know that earthquakes are repeated throughout a long series of ages, in the same spots, like volcanic eruptions. The oldest lavas of Etna were poured out many thousands, perhaps myriads, of years, before the newest, and yet they have produced a symmetrical mountain; and if rivers of melted matter thus continue to flow in the same direction, and towards the same points, for an indefinite lapse of ages, what difficulty is there in conceiving that the subterranean volcanic force, occasioning the rise or fall of certain parts of the earth's crust, may, by reiterated movements, produce the most perfect unity of result?

If denudation of secondary rocks gradual, so also deposition of tertiary. — It follows then, from the facts

* See Vol. II. p. 237., and Vol. III. p. 273.

examined in this and the preceding chapter, that subsequently to the deposition of the chalk a large region composed of secondary strata has been denuded, and that the lapse of many ages must have been required for the entire removal of the materials from the denuded district.

It is no less evident that the transported matter must have been deposited by degrees somewhere else. Are there any tracts in the south-east of England, where we find derivative strata composed of a mixture of such mineral ingredients as would result from the degradation of the secondary groups Nos. 1, 2, 3, 4, 5? The tertiary strata of the London and Hampshire basins answer well to the conditions required by such an origin, for they consist of alternations of variously coloured sands and clays, as do the secondary strata from the group No. 5. to No. 2. inclusive. Some tertiary green-sand, which occurs in parts of the plastic clay formation in the basins of London and Hants, cannot be distinguished mineralogically from a large part of that which is found in the secondary formations below the chalk.

If it be asked, where do we find the ruins of the *white chalk* among our Eocene strata?—The answer is, first, that the flint pebbles, which are associated in such immense abundance with the sands of the plastic clay, are derived evidently from the destruction of chalk, and contain the same fossils: secondly, that as to the soft, white, calcareous matrix, we may suppose it to have been easily reduced to fine sediment, and to have contributed, when in a state of perfect solution, to form the shells of Eocene testacea; or when mixed with the waste of the argillaceous groups, Nos. 2. and 4., which have been peculiarly exposed to denudation, it

may have entered into the composition of the London clay, which contains no slight proportion of calcareous matter. In the *crag* of Norfolk, undoubtedly, we find great heaps of broken pieces of white chalk, with slightly worn and angular flints; but, in this case, we may infer that the attrition was not continued for a long time; whereas, the large accumulations of perfectly rolled shingle, which are interstratified with our Eocene formations, proves that they were acted upon for a protracted period by the waves. We have many opportunities of witnessing the entire demolition of the chalk on our southern coast, as at Seaford, for example, in Sussex, where large masses are, year after year, detached from the cliffs, and soon disappear, leaving nothing behind but a great bank of flint shingle.*

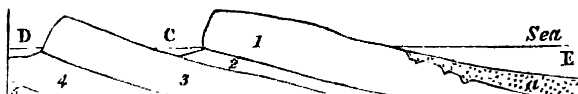
It may also be remarked that the white chalk in the north of England, as in Yorkshire, for example, is much harder than the corresponding formation in the southern counties, where it is now so soft that we may imagine it to have been in the state of mud when submerged beneath the waters of the sea. An original difference of this kind in the degree of induration may explain the fact, that in certain districts gravel composed of chalk-flint occurs without any pebbles of white chalk, while in other regions rounded boulders of white chalk are plentifully intermixed with pebbles of flint.

The similarity, then, of the mineral ingredients of the Eocene secondary strata affords alone some presumption in favour of this newer group having been derived from the wreck of the older series. But it is also natural to expect, that when the formations of the Weald were emerging, there would be some contiguous

* Vol. II. p. 43.

parts of the sea sufficiently deep to receive the drift matter.

Fig. 150.



We may suppose, that while the waves and currents were excavating the longitudinal valleys, D and C (Fig. 150.), "the deposits *a* were thrown down to the bottom of the contiguous deep water E, the sediment being drifted through transverse fissures, as before explained. In this case, the rise of the formations Nos. 1, 2, 3, 4, 5, may have been going on contemporaneously with the excavation of the valleys C and D, and with the accumulations of the strata *a*. There must be innumerable points on our own coast where the sea is of great depth near to islands and cliffs now exposed to rapid waste, and in all these the denuding and reproductive processes must be going on in the immediate proximity of each other.

English Eocene strata rise nearly as high as the denuded secondary districts.—Those geologists who have hitherto regarded the rise and denudation of the lands in the south-east of England as events altogether posterior in date to the deposition of the London clay, will object to the foreging reasoning, that not only certain outlying patches of tertiary strata, but even the central parts of the London and Hampshire basins, attain very considerable altitudes above the level of the sea. Thus the London clay at Highbeach, in Essex, reaches the height of 750 feet; an elevation exceeding that of large districts of the chalk and other

denuded secondary rocks. But these facts do not, I think, militate against the theory above proposed, since I have endeavoured to show that there must have been a long-continued series of elevatory movements in a region where both the degradation and reproduction of strata were in progress.

In order to explain this view, I shall assume that, in the region A (Fig. 151.), the chalk and associated strata

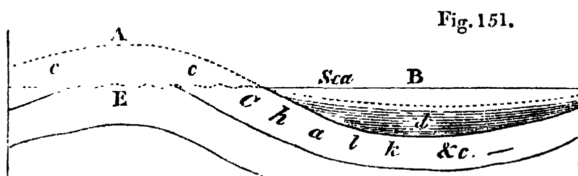


Fig. 151.

are raised and converted into land; while in the adjoining district, B, a continuous part of the same beds remains submerged beneath the sea. During the elevation in A, the mass *c c* is gradually removed by denudation, and its ruins drifted to B, forming the tertiary deposit *d*. The force of water has thus exerted an antagonist power; so that in spite of the upheaving movement, the general outline of the solid surface, or the relative levels of its various parts, are not greatly altered; for the uppermost part of the newer deposit *d* rises nearly as high as the remaining summits of the denuded country A. After all these changes and levelling operations, an elevation to the amount of eight hundred feet in both the regions A and B, would cause the secondary rocks of A to acquire much the same height above the level of the sea, as the tertiary beds would attain in B.

The estimate of Mr. Martin is not, perhaps, exaggerated, when he computes the probable thickness

of strata removed from the highest part of the Forest ridge to be about 1900 feet: so that, if we restore to Crowborough Hill, in Sussex, the beds of Weald clay, lower green-sand, gault, and chalk, which have been removed by denudation, that hill, instead of rising to the height of eight hundred feet, would be more than trebled in altitude, and be about 2700 feet high.* It would then tower far above the highest outliers of tertiary strata which are scattered over our chalk; for Inkpen Hill, in Berkshire, the greatest elevation of chalk in England, rises only 1011 feet above the level of the sea.

Some geologists, who have thought it necessary to suppose all the strata of the London and Hampshire basins to have been once continuous, have estimated the united thickness of the three marine Eocene groups before described, as amounting to 1300 feet, and have been bold enough to imagine a mass of this height to have been once superimposed upon the chalk which formerly covered the axis of the Weald.† Hence they were led to infer that Crowborough Hill was once four thousand feet high, and was then cut down from four thousand to eight hundred feet by *diluvial action*.

But by adopting the view above explained, that the Eocene deposits originated while the chalk and other secondary rocks were rising from the sea and wasting away, we shall find it unnecessary to suppose any removal of formations newer than the chalk, from the central parts of the Weald.

Vertical strata of the Isle of Wight.—A line of vertical and inclined strata, running east and west, or

* Phil. Mag. and Annals, No. 26., New Series, p. 117.

† Martin, ibid.

parallel to the central axis of the Weald, extends, as has been stated, through the Isles of Wight and Purbeck, and through Dorsetshire, and has been observed by Dr. Fitton to reappear in France, north of Boulogne. The same strata which are elevated in the Weald valley are upheaved on this line also; and in the Isle of Wight, all the tertiary strata appear to have partaken in the same movement.*

From the horizontality of the fresh-water series in Alum Bay, as contrasted with the vertical position of the marine tertiary beds, Mr. Webster was at first led very naturally to conclude, that the marine had undergone great derangement before the deposition of the fresh-water strata. It appears, however, from the subsequent observations of Professor Sedgwick†, that these appearances are deceptive; and that at the eastern extremity of the Isle of Wight, part of the fresh-water series is vertical, like the marine. Hence it is now ascertained that, as the chalk is horizontal at the southern extremity of the Isle of Wight, while it is vertical in the centre of that island, so the Eocene strata are horizontal in the north of the island, and vertical in the centre.

An important corollary is deduced from the discovery above mentioned; namely, that the convulsions which brought the Isle of Wight group into their present position were, in a great part, if not entirely, subsequent to the deposition of the fresh-water beds, or upper members of the Eocene formation. They may,

* See Mr. Webster's section, Geol. Trans., vol. ii. First Series, Plate XI.

† Anniv. Address to the Geol. Soc., Feb. 1831, p. 9. Professor Sedgwick informs me that his observations, made in 1827, have recently been confirmed by Professor Henslow.

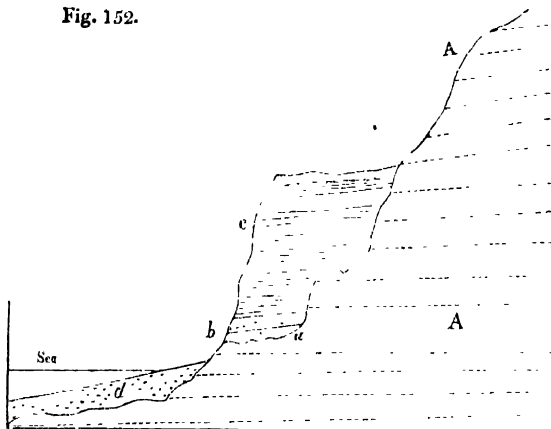
however, have been contemporaneous with those movements which raised the central parts of the London and Hampshire basins to their present height. Referring again to the diagram, Fig. 151. p. 271., we may imagine the series of elevatory movements in the S. E. of England to be divided into two parts: first, that which caused the elevation and denudation of the central axis of the Weald in A; secondly, that which uplifted the denuded surface E, together with the tertiary formations *d*, to their actual height. Now, this last set of movements may have occurred before the close of the Eocene period, and may have produced that curve in the stratified rocks of the Isle of Wight, in which the fresh-water beds there have participated.

At the same time it cannot be denied, that great movements of elevation have been experienced in the south of England since the Eocene period; as, for example, those by which the crag strata attained their present position in Norfolk, Suffolk, and Essex. The formation also called by Mr. Mantell the Elephant Bed, at the foot of the chalk cliffs at Brighton, is not merely a talus of calcareous rubble collected at the base of an inland cliff, but exhibits every appearance of having been spread out in successive horizontal layers by water in motion.

The deposit alluded to skirts the shores between Brighton and Rottingdean, and another mass apparently of the same age occurs at Dover. The phenomena appear to me to suggest the following conclusions:—First, the south-eastern part of England had acquired its actual configuration when the ancient chalk cliff A, *a* was formed, the beach of sand and shingle *b* having then been thrown up at the base of

the cliff. Afterwards the whole coast, or at least that part of it where the elephant bed now extends, sub-

Fig. 152.



A. Chalk with layers of flint dipping slightly to the south.

b. Ancient beach, consisting of fine sand, from one to four feet thick, covered by shingle from five to eight feet thick of pebbles of chalk-flint, granite, and other rocks, with broken shells, &c.

c. Elephant bed, about fifty feet thick, consisting of layers of white chalk rubble, with broken chalk flints, in which deposit are found bones of ox, deer, horse, and mammoth.*

sided to the depth of fifty or sixty feet, and during the period of submergence successive layers of white calcareous rubble *c* were accumulated, so as to cover the ancient beach *b*. Subsequently, the coast was again raised, so that the ancient shore was elevated to a level somewhat higher than its original position.†

* Mantell's Geol. of S. E. of England, p. 32.

† See Mantell's Geol of S. E. of England, p. 32. After re-examining the elephant bed in 1834, I was no longer in doubt of its having been a regular subaqueous deposit.

Eocene alluviums. — The discovery, before mentioned, of the genera Palæotherium and Anoplotherium at Binstead, associated with fossil shells of well-known Eocene species, is interesting, as showing that England, or rather the space now occupied by part of our island, as well as the country of the Paris basin, and Auvergne, Cantal, and Velay, were all inhabited, during the Eocene period, by a class of land animals of a very peculiar type.

Yet we have never found a single fragment of the bones of any of these quadrupeds in our alluviums or cave breccias. In these formations we find the bones of the mastodon and mammoth, of the rhinoceros, hippopotamus, lion, hyæna, bear, and other quadrupeds, all of extinct species. Where, then, are the terrestrial alluviums of that surface which was inhabited by the Paleothere and its congeners?

It is difficult to answer this question; but it seems clear that a peculiar and rare combination of favourable circumstances is required to preserve mammiferous, or indeed any remains in terrestrial alluviums, in sufficient quantity to afford the geologist the means of assigning the date of such deposits. For this reason we are scarcely able, at present, to form any conjecture as to the relative ages of the numerous alluviums which cover the surface of Scotland; a country which probably became land long before the commencement of the tertiary epochs.

Excavation of valleys. — It will be seen that the excavation of the valleys in the S. E. of England has been referred chiefly to the ocean.

Those geologists who contend that the valleys in England are not due to what they term "modern causes," are in the habit of appealing to the fact, that

the rivers in the interior of England are working no sensible alterations, and could never, in their present state, not even in millions of years, have excavated the valleys through which they now flow. A false theory seems to be involved even in the term "modern causes," as if it could be assumed that there were *ancient causes*, differing from those which are now in operation. But if we substitute the phrase "existing causes," we shall find that the argument now controverted amounts to little more than this,—"that in a country free from subterranean movements, the action of running water is so trifling, that it could never hollow out, in any lapse of ages, a deep system of valleys, and, *therefore*, no known combination of existing causes could ever have given rise to our present valleys!"

The advocates of these doctrines, in their anxiety to point out the supposed absurdity of attributing to ordinary causes those inequalities of hill and dale, which now diversify the earth's surface, have too often kept entirely out of view the many recorded examples of elevations and subsidences of land during earthquakes; the frequent fissuring of mountains and opening of chasms; the temporary damming up of rivers by landslips, followed by their sudden and impetuous escape; the deflexion of streams from their original courses; and, more important, perhaps, than all these, the denuding power of the ocean, during the rise of continents from the deep. Few of the ordinary causes of change, whether igneous or aqueous, can be observed to act with their full intensity in any one place at the same time; hence it is easy to persuade those who have not reflected long and profoundly on the working of the numerous igneous and aqueous agents,

that they are entirely inadequate to bring about any important fluctuations in the configuration of the earth's surface.

Recapitulation. — I shall now briefly recapitulate some of the principal conclusions to which I have arrived respecting the geology of the south-east of England, in reference to the nature and origin of the Eocene formations considered in this and the two preceding chapters.

1. In the first place, it appears that the tertiary strata rest exclusively upon the chalk, and consist, with some trifling exceptions, of alternations of clay and sand.

2. The organic remains agree with those of the Paris basin; but the *mineral character* of the English tertiary deposits is extremely different, those rocks in particular which are common to the Paris basin and Central France being wanting, or extremely rare in England.

3. The English Eocene deposits are generally conformable to the chalk, being horizontal where the beds of chalk are horizontal, and vertical where they are vertical; so that both series of rocks appear to have participated in nearly the same movements.

4. It is not possible to define the limits of the ancient borders of the tertiary sea in the south-east of England, in the same manner as can be frequently done in those countries where the secondary rocks are unconformable to the tertiary.

5. Although the tertiary deposits are chiefly confined to the tracts called the basins of London and Hampshire, insulated patches of them are, nevertheless, found on some of the highest summits of the chalk intervening between these basins.

6. These outliers, however, do not necessarily prove that the great mass of tertiary strata was once continuous between the basins of London and Hampshire, and over other parts of the south-east of England now occupied by secondary rocks.

7. On the contrary, it is probable that these secondary districts were gradually elevated and denuded, when the basins of London and Hampshire were still submarine, and while they were gradually becoming filled up with tertiary sand and clay.

8. If, in illustration of this theory, we examine one of the districts thus supposed to have been denuded, we find in the valley of the Weald decided proofs, that an immense mass of chalk and other secondary formations has been removed by the force of water.

9. We may infer, from the existence in the Weald of large valleys along the outcrop of the softer beds, and of parallel chains of hills where harder rocks come up to the surface, that water was the removing cause; and from the shape of the escarpments presented by the harder rocks, and the distribution of alluvium, we may also conclude that the denudation was successive and gradual during the rise of the strata.

10. The materials carried away from the denuded districts were probably conveyed into the depths of the contiguous sea, through channels produced by cross fractures which have since become river-channels, and which now intersect the chalk in a direction at right angles to the general axis of elevation of the country.

11. The analogous structure of the valley of Kingsclere, and of other valleys which run east and west, like the valley of the Weald, but are much narrower, accords with the hypothesis, that they were all pro-

duced by the denuding power of water co-operating with elevatory movements.

12. The mineral composition of the materials thus supposed to have been removed in immense abundance from the valley of the Weald, are such as would, by degradation, form the English Eocene strata.

13. The movements which threw the chalk and the tertiary strata of the Isles of Wight and Purbeck into a vertical position, were subsequent to the formation of the Eocene fresh-water strata of the Isle of Wight, but may possibly have occurred during the Eocene period.

14. But some movements of land in the south of England must have been posterior to the deposition of the crag; and the ancient beach, together with the "elephant bed" at Brighton, seem to imply a subsidence and elevation of comparatively modern date.

15. The masses of secondary rock which have been removed by denudation from the central axis of the Weald would, if restored, rise to more than double the height now attained by any patches of tertiary strata in England.

16. If, therefore, the Eocene strata do not appear to occupy a much lower level than the secondary rocks from the destruction of which they have been formed, it is perhaps because the highest summits of the secondary formations have been cut off during the rise of the land, and thrown into those troughs where we now find the tertiary deposits.

CHAPTER XXIII.

FORMATIONS COMMONLY CALLED SECONDARY AND TRANSITION.

Ancient and modern classification of fossiliferous strata — Formations commonly called secondary and transition — The divisions usually adopted not of equivalent value — Sketch of the principal groups — Cretaceous group (p. 284.) — No species common to the secondary and tertiary rocks — Chasm between the Eocene and Maestricht beds — Duration of secondary periods — Wealden strata — Their relation to the marine groups above and below — Portland "dirt bed" — Oolitic group (p. 298.) — Lias — New red sandstone — Zechstein — Carboniferous group — Old red sandstone — Transition formations — Rock called Greywacké.

It was stated in a former chapter that the first rude attempt to classify rocks in chronological order was that according to which they were arranged in four groups called primitive, transition, secondary, and tertiary—the transition and secondary comprising all the stratified fossiliferous formations older than the tertiary. These ancient divisions, although not yet obsolete, have gradually become less and less fitted to represent the present state of our knowledge. It was never supposed that each of the four sections were of equivalent importance, or, in other words, that that they each comprised a series of monuments relating to equal portions of the ancient history of the earth. It was, however, imagined that they followed each other in

regular chronological order, and that the primary were always older than the transition; that the transition were more ancient than the secondary, and the secondary than the tertiary strata. That this opinion, though generally correct, is not strictly true in regard to the entire series called "primary," whether stratified or unstratified, will appear in the sequel.*

The fossiliferous strata have been variously grouped, according to the comparative value which different geologists have attached to different characters; some having been guided chiefly by the thickness, geographical extent, and mineralogical composition of particular sets of strata; others, by their organic remains. All, however, seem now agreed that it is by a combination of these characters that we must endeavour to decide which sets of strata should be entitled to rank as principal and independent groups. The following is an outline of the arrangement adopted in this work, which will be more fully explained by the Tables at the end of this and the 27th chapter: —

1. Tertiary, or supracretaceous † -	Tertiary.
2. Cretaceous - - -	Secondary.
3. Wealden - - -	
4. Oolite, upper, middle, and lower	
5. Lias - - - -	
6. New red sandstone and muschelkalk	
7. Magnesian limestone and zechstein	
8. Carboniferous - - -	
9. Old red sandstone - -	

* Chap. xxvii.

† For tertiary Mr. De la Beche has used the term "supracretaceous," a name implying that the strata so called are superior in position to the chalk.

10. Ludlow rocks	Upper Silurian	Transition.
11. Wenlock limestone		
12. Caradoc sandstones	Lower Silurian*	
13. Llandeilo flags		
14. Fossiliferous Greywacké	-	

The third group, however, of the above list, or the Wealden formation, although locally of great thickness in the south-east of England, is so partial a deposit that some geologists think it should be merged in the oolite, others in the cretaceous system; to both of which propositions there are objections, as will afterwards appear. The fifth group, or lias, would by many be included in the oolites. The old red sandstone has usually been classed as the lower part of the carboniferous series; but the fossils recently found in it are so distinct from those of the coal, and, on the other hand, from those of the underlying Ludlow rocks, that it seems fairly entitled, on these grounds as well as from its great thickness in parts of England and Scotland to stand as a separate section.

Among other objections to the above classification it may be said that the tertiary group, comprehending all the deposits from the Eocene strata to the Newer Pliocene inclusive, is of greater importance than many of the other divisions. It may also be suggested that the oolitic formation might admit of three subdivisions, each as much entitled to rank as an independent formation as the lias. The following would, perhaps, be a nearer approximation to an arrangement in which the leading divisions would be of equivalent value, as estimated by the successive changes in organic life implied by the imbedded fossil remains and by the geographical extent and thickness of the strata: —

* For explanation of the term "Silurian," see p. 306.

1. Pliocene.
2. Miocene.
3. Eocene.
4. Maestricht and Chalk.
5. Green sand.
6. Wealden.
7. Upper Oolite.
8. Middle Oolite.
9. Lower Oolite.
10. Lias.
11. New red sandstone and Muschelkalk.
12. Magnesian limestone and Zechstein.
13. Carboniferous formation.
14. Old red sandstone.
15. Ludlow rocks.
16. Wenlock limestone.
17. Caradoc sandstone.
18. Llandeilo flags.
19. Fossiliferous Greywacké.

It is not my intention to enter at present upon a detailed description of the fossiliferous formations older than the tertiary, the elucidation of which might well occupy another volume. The observations about to be offered have chiefly for their object to show how far the rules of interpretation adopted for the tertiary formations are applicable to the phenomena of the older sedimentary rocks.

PRINCIPAL GROUPS. (*Descending Series.*)

1. *Cretaceous Group.—Strata from the Chalk of Maestricht to the Lower Green-sand inclusive.*—F. Table I. p. 309.

The principal subdivisions of this group, as it occurs in England and in several countries of the North of Europe, will be found on consulting Table I. Group F. They are six in number, namely;— 1. the Maestricht beds,— 2. the chalk with flints,— 3. the chalk without flints,— 4. the upper green-sand,— 5. the gault,— 6. the lower green-sand. The newest of these deposits is well seen at St. Peter's Mount, Maestricht, and at Ciply, near Mons, reposing on the upper flinty chalk

of England and France. It is a soft yellowish stone, not very unlike chalk, and "includes siliceous masses, which are much more rare than those of the chalk, of greater bulk, and not composed of black flint, but of chert and calcedony." *

It is characterized by a peculiar assemblage of organic remains, perfectly distinct from those of the tertiary period. M. Deshayes, after a careful comparison, and after making drawings of more than two hundred species of the Maestricht shells, has been unable to identify any one of them with the numerous tertiary fossils in his collection. On the other hand, there are several shells which are decidedly common to the calcareous beds of Maestricht and the white chalk; as, for example, the twelve following species, of which the names have been communicated to me by M. Deshayes:—Catillus (Inoceramus) Cuvieri? (specimens imperfect), Plagiostoma spinosa, P. Hoperi, Pecten fragilissimus, Ostrea vesicularis, O. carinata, Crania Parisiensis, Terebratula octoplicata, T. carnea, T. pumilus (magus, *Sow.*), T. Defrancii, Belemnites mucronatus.

But the fossils of the Maestricht beds extend not merely into the white chalk of the French geologists, but into their "chloritic, or green-sand," which corresponds with the upper green-sand of the English geologists. The following five species of shells have been recognized by M. Deshayes as common to the Maestricht beds and the upper green-sand of France:—Plagiostoma spinosa, Ostrea vesicularis, O. carinata, Belemnites mucronatus, and Baculites Faujasii.

Count Munster has shown me, among the fossils

* Fitton, Proceedings of Geol. Soc., 1830.

which he himself collected at Maestricht, three species of ammonite, among which is *A. Rhotomagensis* (Defrance); also a species of Hamite, and Hippurites Desmoulinsi (Golf). The same eminent naturalist has discovered no less than forty species of microscopic cephalopoda in the same formation, all of species distinct from any known either as recent or tertiary, and many of new genera. There is also an ammonite, obtained from the Maestricht limestone by Dr. Fitton, now in the museum of the Geological Society of London. The occurrence of these ammonites and species of kindred genera, such as the Baculite and Hamite, as also the Belemnite, is important, as showing that the subdivision (No. 1.) now under consideration should be classed as the newest member of the secondary series, rather than as a link between it and the tertiary. No shell hitherto found, even in the oldest or Eocene tertiary formations, minutely as these have been investigated, approaches more nearly in its structure to the ammonite than the Nautilus; nor is there any one which bears a considerable resemblance to the Belemnite, the one which comes nearest to it being the Beloptera of the Paris basin. We can scarcely expect, therefore, to discover in existing tropical seas any living representatives of those curious cephalopoda, the ammonites and belemnites, which evidently swarmed in the ocean when the cretaceous and many preceding groups of strata were formed. They even seem to have become entirely extinct, at least in European latitudes, before the commencement of the Eocene period.

The rock commonly known as chalk preserves its peculiar mineral character throughout a considerable area in Europe, but it is rarely of such thickness as in

many parts of the south-east of England, where horizontally stratified masses about one thousand feet thick are composed of it. Its upper member in this country is usually called the "Chalk with flints;" but above this mass there is in some places another deposit of white chalk without flints, which was found, by boring at Diss, in Norfolk, to attain a thickness of 100 feet.* This chalk stretches over a large part of our island, and recurs in the north of Ireland, is found in Denmark and the south of Sweden, and even in Poland and part of Russia. In France it surrounds and underlies the strata of the Paris basin before described (see Map, Fig. 132. p. 222.), from whence it stretches northward into Belgium and the north of Germany, and southward to the basin of the Gironde. I have seen it, still retaining nearly all the same characters, between Bordeaux and Dax; but it changes its aspect greatly on the flanks of the Pyrenees, where its identity can only be established by the similarity of its fossil remains. Even the white chalk, however, varies considerably in its texture, in proportion as we depart from the great central deposit of Europe. In some parts, for example, of the south of France, it becomes oolitic. Here also it contains, together with shells which abound in the north, many other species peculiar to more southern districts, especially of the genera spherulite, hippurite, and nummulite.†

The other divisions of the cretaceous group, Nos. 4, 5, and 6, consist of sands and clays, which have also a wide geographical range. The position of the gault and lower green-sand relatively to the formations of

* Proceedings of Geol. Soc., vol. ii. p. 93.

† Dufrénoy, Bulletin de la Soc. Géol. de France, tom. i. p. 11.

the white and flinty chalk before alluded to, has been elucidated in diagram Fig. 133. p. 237. The fossils of the inferior arenaceous and argillaceous groups are upon the whole very different from those of the chalk before described, but there are many species common to these two great divisions.

The testacea obtained from the entire cretaceous system amount to about one thousand; and if for the sake of classification, we refer every set of strata in Europe which are characterized by these organic remains to one period, we immediately comprehend in it rocks of every variety of mineral composition, yet which always occupy a determinate place in the order of superposition intervening between the tertiary strata and those of the Oolitic period.

In the cretaceous group, thus distinguished, we behold in the Pyrenees and in Spain compact and crystalline marbles, masses of gypsum and salt, puddingstones, red sandstone, thin shales and grits, containing impressions of marine plants, and other rocks, to which there is nothing analogous in formations of the same age in northern Europe.

It appears, by the researches of MM. Boblaye and Virlet, that in the Morea a great cretaceous system occurs, composed of compact and lithographic limestones of great thickness; also of granular limestones, with jasper; and in some districts, as in Messenia, a puddingstone with a siliceous cement more than 1600 feet in thickness.*

It is evident, observe these geologists, from the great range of the hippurite and nummulite limestone, a rock belonging to the same era, that the South of Europe was

* Bull. de la Soc. Géol. de France, tom. iii. p. 149.

occupied at the period of the cretaceous depositions by an immense sea, which extended from the Atlantic Ocean into Asia, and comprehended the South of France, together with Spain, Sicily, part of Italy, and the Austrian Alps, Dalmatia, Albania, a portion of Syria, the isles of the Ægean, coasts of Thrace, and the Troad.

The plants found in the chalk of England and France are chiefly marine. Some wood has been occasionally met with, both in the chalky rock and its flints, having the appearance of being drifted, and commonly marked with the perforations of boring shells, such as the Teredo and Fistulana.* In Sweden, M. Nilsson has found beds of lignite associated with our common chalk fossils†; so that we may conclude that forests grew on the lands of this period, wherever these may have been placed; but as yet their site is mere matter of conjecture.

The testacea, zoophytes, crustacea, and fishes, are marine, and no bones of mammiferous quadrupeds or birds have yet been discovered; but in the Maestricht beds large turtles have been found, and a gigantic reptile, the Mosasaurus, or fossil Monitor, of Maestricht, some of the vertebræ of which appear also in the English chalk.‡ The osteological characters of this oviparous quadruped prove it to have been intermediate between the living Monitors and Iguanas; and, from the size of the head, vertebræ, and other bones, it is supposed to have been twenty-four feet in length.

In reviewing the facts above enumerated, I may first

* Mantell, Geol. of S. E. of England, p. 96.

† Petrificata Suecana, 1827.

‡ See Mantell's Geol. of S. E. of England.

call attention to the important circumstance that no species of fossil shell has yet been found common to the secondary and tertiary formations; a fact stated on the authority of M. Deshayes, who assures me that he has seen no *tertiary* shells in the Gosau beds, supposed by some geologists to be intermediate between the secondary and tertiary formations. On the other hand, some of the most characteristic species of Gosau occur in the green-sand beneath the chalk, at Ciply, south of Mons, in Belgium, and at some neighbouring places which I have visited. Count Munster also informs me, that the zoophytes which he possesses from the Gosau beds differ specifically from any which he knows as tertiary. I mention this in the hope that the identifications which have been made of Gosau and tertiary species may be re-examined with scrupulous care, for, if confirmed, they would be of the greatest theoretical interest.

This marked discordance in the organic remains of the two series is not confined to the testacea, but extends, so far as a careful comparison has yet been instituted, to all the other departments of the animal kingdom, and to the fossil plants. Dr. Agassiz, whose great work on fossil fish is now in progress of publication, has discovered no species of fish common to the secondary and tertiary rocks.

There appears, then, to be a greater chasm between the organic remains of the Eocene and Maestricht beds, than between the Eocene and Recent strata; for there are some living shells in the Eocene formations, while there are no Eocene fossils in the newest secondary group. It is not improbable that a longer interval of time may be indicated by this greater dissimilarity in fossil remains. In the 3d and 4th

chapters I endeavoured to point out that we have no right to expect, even when we have investigated a greater extent of the earth's surface, that we shall be able to bring to light an unbroken chronological series of monuments from the remotest eras to the present; but, as we have already discovered a long succession of deposits of different ages, between the tertiary groups first known and the *recent* formations, so we may, perhaps, hereafter detect an equal, or even greater series, intermediate between the Maestricht and Eocene strata.

The different subdivisions of the cretaceous group (No. 1.), extending from the chalk of Maestricht to the lower green-sand inclusive, may, perhaps, relate to a lapse of ages as immense as the united tertiary periods, of which the eventful history has been sketched in this work. Such a conjecture, at least, seems warranted, if we can form any estimate of the quantity of time, by comparing the amount of vicissitude in animal life which has occurred during its lapse.

2. *The Wealden, or the Strata from the Weald Clay to the Purbeck Limestone inclusive.* — G, Table I. p. 309.

It will be seen by the Table I. p. 309., that in the South of England this group may be divided into three formations — the Weald clay, the Hastings sands, and the Purbeck beds, which are all characterized by the remains of fresh-water animals; whereas the cretaceous strata which are superimposed upon the Wealden, in the south-east of England, contain fossils of marine species.*

* The term Wealden was suggested by Mr. Martin, and will be found of great convenience.

The position of these beds has been indicated in diagram Fig. 133. page 237., and the map (Plate XV.) will show the superficial area occupied by them in Kent, Sussex, Surrey, and Hampshire. It must not be supposed, however, that they terminate at the points where they happen to be covered by the cretaceous system. The same group has been ascertained to extend from west to east (from Lulworth Cove to the boundary of the Lower Boulonnois), about 200 English miles; and from north-west to south-east (from Whitchurch to Beauvais), 220 miles; the depth or total thickness of the beds, where greatest, being about 2000 feet.* The general appearance of the clays and sands, and of the subordinate beds of limestone, grit, and shale, and of the imbedded shells, recalls so precisely that of many tertiary formations of fresh-water origin, that it is only after having determined the species of organic remains that we recognize a discordance in character as great as might have been anticipated when strata above and below the chalk were compared.

The vegetable remains belong, some of them, to plants which appear to have held an intermediate place between the Equiseta and Palms, as the Clathraria discovered by Mr. Mantell; while others approach to arborescent ferns, the species being very peculiar, and not known in any other deposit, whether of higher or inferior antiquity.†

The shells of the Wealden are almost exclusively fluviatile; and, as is usual in assemblages of fresh-water testacea, a few species only are found, while the individuals are very numerous, sometimes forming the

* Fitton's Geol. of Hastings, p. 58.

† Mantell, Geol. of S. E. of England, chap. xi.

principal component of entire beds of limestone. Shells of the Cypris, also, a fresh-water animal, before mentioned as occurring in the lacustrine deposits of Auvergne, are profusely distributed throughout the Wealden. Of this genus several species have been discovered and figured by Dr. Fitton.*

Some fish, also, of forms resembling known fluviatile genera, have been met with; but the remains of reptiles present the most remarkable feature in this group. Some of these belong to turtles, such as the Trionyx, a genus now occurring in fresh-water in tropical regions: others are referrible to the genus Emys. Of Saurian lizards there are at least five genera; the Crocodile, Plesiosaur, Megalosaur, Iguanodon, and Hylæosaur. The Iguanodon, of which the remains were first discovered by Mr. Mantell, was an herbivorous reptile, and was regarded by Cuvier as more extraordinary than any with which he was acquainted: for the teeth, though bearing a great analogy to the modern Iguanas which now frequent the tropical woods of America and the West Indies, exhibit many striking and important differences. It appears that they have been worn by mastication; whereas the existing herbivorous reptiles clip and gnaw off the vegetable productions on which they feed, but do not chew them. Their teeth, when worn, present an appearance of having been chipped off, and never, like the fossil teeth of the Iguanodon, have a flat ground surface, resembling the grinders of herbivorous mammalia.† From the large bones, found in great numbers near these teeth, and fairly presumed to belong

* See Trans. of Geol. Soc., vol. iv., Second Series, now in the press.

† Mantell, Geol. of S. E. of England, p. 277.

to the same animal, it is computed that the entire length of this reptile could not have been less than seventy feet.

The bones of birds have been found in the Wealden; but in no part has any fragment of the skeleton of a mammiferous quadruped been obtained. With this exception, to which I shall presently revert, the strata of the Wealden present such characters as we might look for in the deposits of the deltas now forming at the mouths of large rivers in tropical climates.

The Wealden, as was before explained, is covered by the marine cretaceous system, and reposes upon another, which is, in like manner, a purely marine deposit; namely, the uppermost member of the Oolite, or group H, Table I. p. 310.

This intercalation of a great fresh-water formation between two others of marine origin is a remarkable fact, and attests, in a striking manner, the great extent of former revolutions in the position of sea and land. In those sections where the junction of the fresh-water and cretaceous system is seen, the beds of the lower green-sand have been observed to repose conformably upon those of the subjacent Weald clay. There is no indication of disturbance: "To all appearance the change from the deposition of the fresh-water remains to that of the marine shells may have been effected simply by a tranquil submersion of the land to a greater depth beneath the surface of the waters."*

At the point of contact of the *inferior* division of the Wealden or "Purbeck beds," with the more ancient marine system, a very curious phenomenon is observed: the fresh-water calcareous strata repose, both in Portland and Purbeck, upon the oolitic limestone, called

* Dr. Fitton, Geol. of Hastings, p. 28.

the Portland stone, which abounds with Ammonites, Trigoniæ, and other marine shells. Between the two formations there intervenes "a layer, about a foot in thickness, of what appears to have been an ancient vegetable soil; it is of a dark brown colour, contains a large proportion of earthy lignite, and, like the modern soil on the surface of the island, many water-worn stones. This layer is called the "dirt-bed" by the quarrymen; and in, and upon it, are a great number of silicified trunks of coniferous trees, and plants allied to the recent *cycas* and *zamia*. Many of the stems of the trees, as well as the plants, are still erect, as if petrified while growing undisturbed in their native forest; the trees having their roots in the soil, and their trunks extending into the superincumbent strata of limestone."*

Traces of this vegetable earth, occupying the same relative situation, have been observed by Dr. Fitton in the cliffs of the Boulonnois, on the opposite coast of France.† Dr. Buckland and Mr. De la Beche have also ascertained that many of the stumps of trees remain erect, with their roots attached to the black soil on which they grew, their upper part being imbedded in the limestone; from which they infer, "that the surface of the subjacent Portland stone was for some time dry land, and covered by a forest, and probably in a climate such as to admit the growth of the modern Zamia and Cycas." ‡

* Mantell, Geol. of S. E. of England, p. 336.— See also papers by Mr. Webster, Dr. Buckland, and Mr. De la Beche, Geol. Trans., Second Series, vol. ii. Mr. Webster was, I believe, the first to notice the erect position of the stems.

† Geol. of Hastings. Geol. Proceedings, vol. i. p. 9.

‡ Proceedings of Geol. Soc., April, 1830.

It seems a legitimate deduction from the data above explained, that the marine formations of an antecedent period (that of the oolite) had become land throughout a portion of the space now occupied by the South of England and the opposite coast of France; and that this land then sank down, with its forests, and became submerged beneath the waters of a great river, just as the region around Sindree, in Cutch, subsided in 1819, and was permanently laid under water, being at one time occupied by the fresh water of the Indus.* The country may then have continued to subside, until a thickness of two thousand feet of fluviatile sediment had been gradually accumulated; and this deposit, or delta, by a continuation of the same depressing operations, may, in its turn, have become buried deep beneath the sea in which the chalk was formed.

I shall not enter farther into these speculations at present, but proceed to inquire how far the Wealden is connected by its fossil remains with the overlying or subjacent formations. First, we may ask whether there are any species of fossil animals or plants common to the fresh-water group and to the oolitic system. I am aware of one example only, the Megalosaurus Bucklandi; for the teeth and bones of this great saurian occur in the Stonesfield oolite and the Hastings sands, the remains in both cases having been referred by Cuvier to the same species. There are also some *generic* forms both of reptiles and fish common to the Oolite and Wealden, and not yet discovered in the Chalk. Vertebræ, for example, of the Plesiosaurus are not confined to the oolite and lias, but have been also found in the Wealden; and the Lepidotus, a genus of fish

* See Vol. II. p. 237., and Vol. III. p. 278., and Plate V.

very characteristic of the Wealden, is unknown in the cretaceous group, while it is abundant in the oolitic series. On the other hand, the same Iguanodon Mantelli, which is so conspicuous a fossil in the Wealden, has recently been discovered near Maidstone in the overlying Kentish rag, a marine limestone of the lower green-sand. From this fact we may infer that some of the saurians which inhabited the country of that great river, which by its sediment produced the Wealden strata, continued to live when part of the country had become submerged beneath the sea. Thus, in our own times, we may suppose the bones of large alligators to be frequently entombed in recent fresh-water strata in the delta of the Ganges. But if part of that delta should sink down so as to be covered by the sea, marine formations might begin to accumulate in the same space where fresh-water beds had previously been formed; and yet the Ganges might still pour down its turbid waters in the same direction and carry the carcasses of the same species of alligator to the sea, in which case their bones might be included in marine as well as in subjacent fresh-water strata.

Near Beauvais, in France, there is a small valley of elevation and denudation, closely resembling in structure that of the Weald, and called the country of Bray, where the green-sand crops out from beneath the chalk, and where strata, for the most part like those of the Wealden, appear beneath the green-sand. One member of the series, a fine whitish sand, contains impressions of ferns, considered by M. Adolphe Brongniart as identical with Lonchopteris Mantelli, a plant found frequently in the Wealden. I examined part of the valley of Bray in company with M. Graves, in 1833, and I observed that the sand last mentioned, with its

vegetable remains, was intercalated between two sets of marine strata, containing trigoniæ, and referred, by French geologists, to the lower green-sand. In the same country of Bray, and associated with the same formation, is a limestone resembling the Purbeck marble, and containing a Paludina which seems specifically identical with that of Purbeck.

There are some few species, therefore, of the Wealden common on the one hand to the overlying cretaceous group, and on the other to the subjacent oolite; but the connection hitherto established is so slight that the era of the fresh-water deposit may have been separated by a wide interval of time from the periods when the animals either of the oolitic or cretaceous periods predominated.

3. *Oolite, or Jura Limestone Formation.*—H, Table I. p. 310.

The different subdivisions which have been made for the classification of the rocks of this group in England are enumerated in Table I. p. 310. It consists of limestone, clay, marl, and sand; which, considered in the aggregate, retain the same lithological characters throughout a considerable part of England, France, and Germany. It is not to be expected that we should be able to follow the different members of the English series throughout Europe, as they vary greatly, both in mineral and organic characters, in their course throughout different parts of our own island; but, as the fossils of the higher, middle, and lower parts of the series are not the same, it may be possible, by their aid, to establish subordinate groups of great utility.

The coral rag of England, and analogous zoophytic

limestones of the oolitic period in different parts of Europe, bear a resemblance to the coralline formations now in progress in the seas of warmer latitudes.

In the lithographic limestone of Solenhofen, belonging to one of the upper members of the series, a great variety of organic remains is found. Among these I have seen in the museum of Count Munster no less than seven *species* of flying lizards, or Pterodactyls, six saurians, three tortoises, sixty species of fish, forty-six of crustacea, and twenty-six of insects. The number of testacea is comparatively small, as also of plants, which are all marine. Count Munster had determined 237 species from the Solenhofen slate when I saw his collection in 1833. The extreme fineness of the sediment has, in this instance, allowed impressions of some of the most delicate and soft parts of various animals to be preserved; as of the belemnite and several insects.

In the Stonesfield slate (see Table), the remains of many reptiles have been found associated with marine shells, and the jaws of at least two species of small mammiferous quadrupeds of a genus allied to the Didelphys, or Opossum.* It is very remarkable, that these fossils afford the only exception yet known to the apparent absence of all terrestrial mammalia from the islands and continents which existed anteriorly to to the Eocene period.

4. *Lias.* I, Table I. p. 311.

The English provincial name of Lias has been very generally adopted for a formation of argillaceous limestone, marl, and clay, usually found in conformable stratification to the rocks of the oolite group before de-

* See Fig. 2 and 3. Vol. I. pp. 232, 233.

scribed. Some geologists regard the lias as the lowest member of the oolite group, several species of organic remains being common to it and to the inferior oolite. If we draw a line between these formations, the separation will be somewhat arbitrary, but may be, nevertheless, convenient; as both the oolite group and the lias will still comprehend a great thickness of strata, characterized, when viewed on the great scale, by assemblages of distinct fossils. The lias retains a uniform mineralogical character throughout a great part of England, France, and Germany; and this circumstance may facilitate the attempt to ascertain the contemporaneous existence of a sufficiently numerous set of fossil plants and animals to enable us to determine the equivalent groups of distant countries.

The remains of reptiles, those of saurians in particular, are very common in the liassic rocks in several parts of England, especially of the genera Ichthyosaurus, Plesiosaurus, and crocodile.

5. *New Red Sandstone group*, K, Tab. I. p. 311. (*including the Muschelkalk of the Germans*).

The deposits which are referrible to the interval which separated the lias from the great coal formation may be divided into two principal groups: first, the New Red Sandstone; secondly, the Magnesian Limestone. The New Red Sandstone of England, accompanied by beds of gypsum and rock salt, is almost entirely destitute of organic remains; but the Muschelkalk of Germany, which is referrible to the same period, and has no precise equivalent among the English strata, contains many fossils of species distinct from those of the lias, or subjacent magnesian limestone.

This calcareous formation (Muschelkalk) is inter-

posed in Bavaria and Wurtemburg, between two others; the overlying "Keuper," or variegated marls, with which it alternates at the junction, and the red mottled sandstone ("bunter sandstein") on which it rests. The plants found by Count Munster in this last, and in the "Keuper," are so similar, as to induce that geologist to regard all the three groups thus connected as belonging to one period; and in confirmation of the same opinion, M. Agassiz finds the same species of fish to be common to the three groups.

6. *Magnesian Limestone (Zechstein of the Germans).* L, Tab. I. p. 312.

This formation consists in England for the most part of a yellowish limestone, in which a small number only of organic remains are preserved, but these are referrible to peculiar and characteristic species.

So also in the zechstein of the Germans, a limestone of this period, and in its accompanying copper slate, the the same or very similar fossils occur. At Mansfeld in Westphalia, for example, fish are found of the extinct genus Palæothryssum, only known in strata of this group. Dr. Agassiz informs me that he has not as yet been able to identify any species from Mansfeld with any one of those found in England, but the genus appears characteristic of the era under consideration.

7. *Carboniferous Group, comprising the Coal-measures, and the Mountain Limestone.* M, Tab. I. p. 312.

The rocks of this group consists of limestone, shale, sandstone, and conglomerate; interstratified with which are large beds of coal, a substance now universally admitted to be of vegetable origin. Several hundred species of plants have been found in the shales and

sandstones associated with the coal, and all are, with few exceptions, of species differing widely from those which mark the vegetation of other eras. Some remarks have been offered in the first book*, respecting the known geographical extent of the coal formation and the tropical character of its flora, and of the shells and corals of the carboniferous or mountain limestone.† I there adduced arguments for inferring that the lands in northern latitudes consisted, for the most part, at that remote era, of small islands; and mentioned the absence of large saurian remains, the insular character of the flora, and the deposition of the strata, as favouring that opinion.

But although the higher latitudes of the northern hemisphere probably formed at that time a great archipelago, they must have contained some islands of sufficient magnitude to allow of the existence of rivers, lakes, and marshes, where fresh-water strata were accumulated. A fresh-water limestone has been discovered and described by Dr. Hibbert at Burdiehouse near Edinburgh, as lying beneath marine strata of the carboniferous group. Instead of containing fossil corallines or encrinites, like the mountain-limestone, the formation in question contains land plants in great abundance, and minute entomostraca allied to the genus Cypris ‡ and several fish.

Mr. Hutton states that, in part of the coal-field of Northumberland and Durham, fossil shells of a species of Unio occur in considerable abundance in a shale containing plants of the carboniferous period, and overlying a bed of coal. The coal has been worked out from

* Vol. I. pp. 196. to 198. † Vol. I. p. 153.
‡ See above, p. 163.

beneath the shells, which have been already proved to extend over an area five thousand feet square. The shelly stratum is about eighteen inches thick; and the animals have evidently died at various ages, the shells being of every size. This accumulation of bivalves of one species, and of this form, seems clearly to indicate the continuance on the spot of a body of fresh-water, such as might be found in the estuary of a river.*

In the Shropshire coal-field near Bridgnorth, and in other places, Mr. Murchison has shown that the upper coal-measures contain a subordinate bed of limestone, which may be termed lacustrine, as a small species of Planorbis is plentifully imbedded in it.†

8. *Old Red Sandstone.* N, Table I. p. 313.

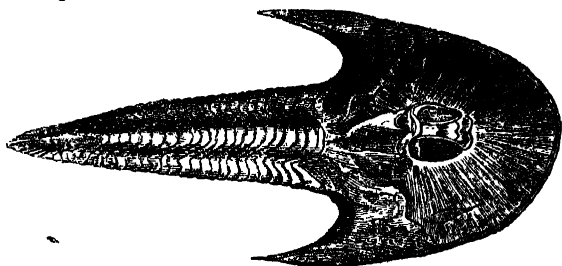
Beneath the coal-series in the northern part of Fifeshire in Scotland, and the southern half of Forfarshire, a formation occurs of great thickness, composed of red marl, conglomerate, red and white sandstone, and shales of various colours, for the most part devoid of organic remains. In some of the shales, however, impressions of plants apparently marine, have been met with, and in the flaggy sandstones containing a slight admixture of carbonate of lime, the scales and other remains of fish are not unfrequent. They belong to a genus named by Dr. Agassiz "Cephalaspis," or "buckler-headed," from the extraordinary shield which covers the head. (See Fig. 153.) This peculiar form of fish, which is quite unknown in the coal-strata, seems characteristic of the old red sandstone generally; for it is found in Herefordshire and other counties of England and Wales, where the old red-sandstone is

* Fossil Flora, by Lindley and Hutton, No. 10.

† Proceedings of Geol. Soc., No. 38. p. 119.

largely developed. All the animal and vegetable remains hitherto discovered in this series are dis-

Fig. 153.



Cephalaspis Lyellii, Agass. Length 6¾ inches.

This figure is from a specimen now in my collection, which I procured at Glammis in Forfarshire. An account of it will appear in the work on Fossil Fish, by Dr. Agassiz, who named the species after me.

tinct from those of the overlying coal, or subjacent transition strata.

9. *Transition, or Greywacké Formations.* O. & P. Table I. p. 313.

Continental and English authors have not always been agreed where the line of separation should be drawn between the secondary and transition formations. Some of them, for example, have included the carboniferous group in the secondary, others in the transition system. But in England the old red sandstone has been generally considered as the lowest member of the secondary series.

The name of transition was first given by Werner to certain sedimentary deposits consisting, in the Hartz and many parts of Germany, of arenaceous and brecciated rocks which alternate with argillaceous schist, and are sometimes associated with corallines and

shelly limestones. These were supposed to have been the earliest formed strata when the ocean first became habitable by aquatic beings. Although the principal members of this group, where it is largely developed, are evidently of mechanical origin, they often alternate with beds of quartz and argillaceous schist, not distinguishable mineralogically from crystalline rocks classed by Werner as primitive. Hence, as was before stated, the term transition was adopted to express the theory that, at this period, the causes which had given rise to crystalline formations were still in action; while those which produced stratified sedimentary rocks, including organic remains, were also beginning to operate.

The characteristic group called in German "Grauwacke" is an aggregate of small fragments of quartz, Lydian stone, and argillaceous schist, cemented together by argillaceous matter. But far too much importance has been attached to this kind of rock, as if it were peculiar to a certain epoch in the earth's history, whereas it is only an accidental variety of argillaceous sandstone, probably in some cases altered by heat. There are parts of England and Sweden where fossiliferous strata more ancient than the old red sandstone are largely developed, and yet where no rocks answering mineralogically to the Greywacké of the Germans are discoverable.

The first great step towards a general table of superposition of the British fossiliferous groups below the old red-sandstone, each distinguished by certain mineral characters and organic remains, has recently been made by Mr. Murchison, and his arrangement has been adopted in Table I. p. 313.

Mr. Murchison has had an opportunity of tracing the succession of deposits in a regular descending

series, from the old red sandstone with which they are in part covered, to the subjacent and unconformable greywacké rocks of South Wales. As far as his examination has hitherto proceeded, all the species of zoophytes and shells differ from those of the carboniferous limestone; while the fossils of his four great subdivisions are distinct from each other.*

He has proposed the term "Silurian," as a general name for this whole system of rocks, derived from "Silures," the principal tribe of Celts or ancient Britons, who occupied part of Wales and the bordering counties of England, where these ancient fossiliferous strata are most distinctly exhibited. The Ludlow rocks and the Wenlock limestone may be classed as the Upper Silurian group, being the deposits which are immediately below the old red-sandstone; while the Caradoc sandstones and Llandeilo flags form the Lower Silurian group. Below all these there are other fossiliferous rocks which, in Wales, are unconformable to the Silurian strata.

Among the fossils of the Silurian formations, zoophytes and crinoidea are the most numerous; and some of the limestones, which are in great part composed of them, agree in their general character with those now in progress in seas where stone-corals are abundant. The Trilobite, a singular crustaceous animal, of which no living species is known, is also characteristic of the rocks of this period; so also the Orthocera, a chambered univalve, of which certain species are found in the carboniferous limestone, but hitherto in no newer deposit. On the other hand, some of the shells belong to recent genera, as the



* Proceedings of Geol. Soc. London, No. 34. 1834.

Terebratula, of which there is a great variety. The only vertebrated remains hitherto found are a few bones of fishes. The shells and zoophytes of these formations have been studied in Germany by Count Munster, Professor Goldfuss, and M. Steininger. In Nassau, M. Stift has endeavoured to classify the different subdivisions of the same series chiefly by reference to their mineralogical characters. M. Hisinger also, who has recently published a geological map of the south of Sweden, as well as Professor Wahlenberg and the late M. Dalman, have described and figured many fossil productions from these strata in Sweden.

With this "Silurian" group I shall conclude; for although other divisions may hereafter be requisite, it does not appear that any antecedent periods can yet be established on the evidence of a distinct assemblage of fossil remains. Traces of organization do undoubtedly occur in rocks of still higher antiquity; but they cannot be referred to a distinct geological period, until we have obtained data for determining the specific characters of a considerable number of fossils.

The annexed table will explain the order of superposition of the successive groups of fossiliferous strata hitherto established in Europe; it should be remembered, however, that it is in a small part of western Europe only that almost all this series of monuments has been discovered.

TABLE I.

TABLE I.

Showing the Order of Superposition, or Chronological Succession, of the principal European Groups of Sedimentary and Fossiliferous Strata.

This Table is also referred to in the Glossary.

Periods and Groups.		Names of the principal Members and Mineral Nature of the Formation, in Countries where it has been most studied		Some of the Localities where the Formation occur
I. Recent Period.		The deposits of this period are for the most part concealed under existing lakes and seas.		
I. Recent Period.	A.	Consolidated sandy and gravelly beds (*a*), travertin limestones (*b*), calcareous sandstones with broken shells (*c*), coral limestone, consisting of corals, shells, &c. (*d*), compact limestone (*e*).		*a.* Delta of the Rhone. *b.* Tivoli, and other parts of Italy. *c.* Shore of island of Guadaloupe. *d.* Coral reefs in Pacific, &c. *e.* Bermudas.
II. Tertiary Period.	B. Newer Pliocene.	Marine. Limestone, sands, clays, sandstones, conglomerates, marls with gypsum; containing *marine* fossils (*a*).	Fresh-water. Sands, clays, sandstones, lignites, &c.; containing *land* and *fresh-water* fossils (*b*).	*a.* Sicily, Ischia. *b.* Colle in Tuscany.
II. Tertiary Period.	C. Older Pliocene.	*Subapennine marl, Subapennine yellow sand, English "crag,"* and other deposits, as in B., containing *marine* fossils (*a*).	Similar deposits to B.; containing *land* and *fresh-water* fossils (*b*).	*a.* Subapennine formations, Perpignan, Nice, Norfolk, and Suffolk. *b.* Near Sienna, &c.
II. Tertiary Period.	D. Miocene.	*Faluns of the Loire,* and other deposits varying in mineral composition, as those in B. and C., containing *marine* fossils (*a*).	Similar deposits to B. and C.; containing *land* and *fresh-water* fossils (*b*).	*a.* Touraine, Bordeaux, Valley of Bormida, Superga near Turin, Basin of Vienna. *b.* Saucats, twelve miles south of Bordeaux.

TABLE I. — *continued.*

Periods and Groups		Names of the principal Members and Mineral Nature of the Formation, in Countries where it has been most studied		Some of the Localities where the Formation occurs.
III. TERTIARY PERIOD — *continued.*	E. Eocene.	*Calcaire grossier* (*a*), *London clay*, sands, sandstones, &c., with *marine* fossils (*b*).	*Calcaire siliceux* — sandstones and conglomerates, red marl, green and white marls, limestone, gypseous marls,— with *land* and *fresh-water* fossils (*c*).	*a.* Paris basin. *b.* Paris, London, and Hampshire basins, Isle of Wight. *c.* Paris basin, Isle of Wight, Auvergne, Velay, Cantal.
III. SECONDARY PERIOD.	F. Cretaceous Group.	1. *Maestricht Beds.* — Soft yellowish-white limestone with siliceous masses, resembling chalk (marine).		St. Peter's Mount, Maestricht. Ciply, near Mons.
		2. *Chalk with flints* (marine).		North and South Downs and parts of the intervening Weald of Kent, Surrey, and Sussex. Yorkshire; North of Ireland. Beauvais, France.
		3. Chalk without flints (marine).		
		4. *Upper green sand* (marine).— Marly stone, and sand with green particles; layers of calcareous sandstone.		
		5. *Gault* (marine). — Blue clay, with numerous fossils, passing into calcareous marl in the lower parts.		
		6. *Lower green sand* (marine). — Grey, yellowish, and greenish sands, ferruginous sands and sandstones, clays, cherts, and siliceous limestones.		
	G. Wealden Group.	1. *Weald Clay* (fresh-water). — Clay, for the most part without intermixture of calcareous matter, sometimes including thin beds of sand and shelly limestone.		1, 2. Extensively deve-

TABLE I.—*continued.*

Periods and Groups.		Names of the principal Members and Mineral Nature of the Formation, in Countries where it has been most studied.	Some of the Localities where the Formation occurs.
III. Secondary Period — *continued.*	G. Wealden Group, *continued.*	2. *Hastings sands* (freshwater). — Grey, yellow, and reddish-brown sands, sandstones, clays, calcareous grits passing into limestone.	loped in the central parts of Kent, Surrey, and Sussex. 3. Isle of Purbeck, in Dorsetshire.
		3. *Purbeck beds* (freshwater). — Various kinds of limestones and marls.	
	H. Oolite, or Jura Limestone Group.	1. *Portland beds* (marine). — Coarse shelly limestone, fine-grained white limestone, compact limestone — all more or less of an oolitic structure; beds of cherts.	Isle of Portland, Tisbury in Wiltshire, Aylesbury.
		2. *Kimmeridge clay* (marine). — Blue and greyish-yellow slaty clay, containing gypsum, bituminous slate (Kimmeridge coal).	Near Kimmeridge on coast of Dorsetshire — Sunning Well, near Oxford.
		3. *Coral rag* (marine). — Calcareous shelly freestones, largely oolitic; coarse limestone, full of corals; yellow sands; calcareous siliceous grits.	Headington, near Oxford — Farringdon, in Berkshire — Calne and Steeple Ashton, in Wiltshire — Somersetshire.
		4. *Oxford clay* (marine). — Dark blue tenacious clay, with septaria, bituminous shale, sandy limestone (Kelloway rock), iron pyrites, gypsum.	New Malton, in Yorkshire — Lincolnshire — Cambridgeshire — Huntingdonshire, and midland counties — abundantly near Oxford — Somersetshire — Dorsetshire.
		5. *Cornbrash* (marine). — Grey or bluish rubbly limestone, separated by layers of clay.	Malmsbury, Atford, Wraxall, Chippenham.

TABLE I.—*continued.*

Periods and Groups.	Names of the principal Members and Mineral Nature of the Formation, in Countries where it has been most studied.	Some of the Localities where the Formation occurs.
III. SECONDARY PERIOD — *continued.* H. Oolite, or Jura Limestone Group — *continued.*	6. *Forest marble* (marine).—Calcareo-siliceous sand and gritstone; thin fissile beds of limestone, with clay partings; coarse shelly limestone.	Whichwood Forest, Oxfordshire — Frome, south-east of Bath.
	7. *Great oolite* (marine).—White and yellow oolitic calcareous freestone, coarse shelly limestone, layers of clay. Oolitic limestone, with remains of land animals, birds, amphibia, plants, sea-shells (*a*).	Bath—Burford in Oxfordshire—Bradford in Wiltshire. *a.* Stonesfield, near Woodstock, Oxfordshire.
	8. *Fuller's earth clay* (marine).—Clay containing in some places fuller's earth.	Near Bath.
	9. *Inferior oolite* (marine).—Soft freestone, sand with calcareous concretions.	Cotteswold Hills — Dundry Hill, near Bristol.
	Limestones of various qualities, clays, sands, and sandstone, containing the same fossils as those occurring in the series of the oolitic group of England, constitute the main body of the Jura chain of mountains, and cover vast tracts of country in Germany.	
I. Lias Group.	*Lias* (marine).—Shale and sandy marlstone. Blue, white, and yellow earthy limestone, usually in thin beds, interstratified with clay, often slaty and bituminous.	Lyme Regis in Dorsetshire, and in many parts of Somersetshire — Yorkshire — in Sutherlandshire, the Hebrides, and North of Ireland. In France, as at Metz, and to a considerable extent in Germany, as in the Swabian Jura.
K.	1. *Keuper, or variegated marls.*—Red, grey, green, blue, and white marls, sandstones, conglomerates, and shells, containing gypsum and rock-salt.	Neighbourhood of Vosges mountains, and many parts of Wurtemberg and Westphalia, Nuremberg.

TABLE I. — *continued.*

Periods and Groups		Names of the principal Members and Mineral Nature of the Formation, in Countries where it has been most studied.	Some of the Localities where the Formation occurs.
III. Secondary Period — *continued.*	K. New Red Sandstone Group — *continued.*	2. *Muschelkalk* (marine). — Grey, blue, and blackish limestone, with alternating clay and marl, and with siliceous layers, and nodules.	Extensively developed in Germany and France. Hitherto no beds in England have been identified with the formation.
		3. *Variegated (Bunter) sandstone.* — Red, white, blue, and green siliceo-argillaceous sandstone, often micaceous, and containing gypsum and rock-salt.	Nottinghamshire — Yorkshire. Stuttgardt.
	L. Magnesian Limestone Group.	1. *Magnesian limestone* (*a*) (marine). — Marl-slate, shelly limestone, variegated marls, yellow magnesian limestone. *Zechstein of Germany* (*b*) — limestone — marl-slate, containing copper ore, and impressions of fish.	*a.* Nottinghamshire, Derbyshire, Yorkshire, Durham, Northumberland. *b.* Mansfeld in Thuringia
		2. *Red conglomerate.* — Sandstones, conglomerates, sands, and marls.	Neighbourhood of Exeter
	M. & N. Carboniferous Group.	1. *Coal measures* (fresh-water and marine). — Sandstones, grits, conglomerates, clays, with ironstone, shales, and limestone, interstratified with beds of coal.	Northumberland, Durham, Yorkshire, Lancashire, Staffordshire, Somersetshire, South Wales, Valleys of the Forth and Clyde. District of Liege, Westphalia, Silesia, Bohemia, &c.
		2. *Mountain limestone* (marine). — Grey, compact, and crystalline limestone, abounding in lead ore in North of England, and alternating with coal measures in Scotland.	Mendip Hills, Derbyshire, Yorkshire, Durham, Northumberland, Lanarkshire, Linlithgowshire, many parts of Ireland. North-west of Germany, Belgium, North of France

TABLE I. — *continued.*

Periods and Groups			Names of the principal Members and Mineral Nature of the Formation, in Countries where it has been most studied.	Some of the Localities where the Formation occurs.
		N.	1. *Old red sandstone.* — Coarse and fine siliceous sandstones and conglomerates of various colours, red predominating.	Extensively developed in Shropshire and Herefordshire, Brecknockshire, Dumfries-shire, Forfarshire. Silesia, Bohemia.
IV. Transition Period.	Silurian Group.	O.	1. *Ludlow rocks* (marine). — Argillaceous limestone, sandy shale.	Ludlow Castle, Shropshire; Aymestry and Woolhope, Herefordshire.
			2. *Wenlock limestone* (marine). — Coralline limestone and argillaceous shale, with nodules of earthy limestone.	Wenlock Edge, Shropshire, Dudley, Worcestershire.
			Caradoc sandstones (marine). — Shelly limestone and micaceous sandstone, quartzose grits and sandy limestones.	Horderly, Shropshire; and May Hill, Gloucestershire. East flank of Wrekin and Caer Caradoc, Shropshire.
			4. *Llandeilo flags* (marine). — Calcareous flags, sandstone and schist.	Llandrindod, near Builth, Radnorshire. Llandeilo, Caermarthenshire.
		P.	Fossiliferous greywacké, and rocks older than the Silurian, but in which no distinct assemblage of organic remains have as yet been specifically determined.	

CHAPTER XXIV.

ANALOGY OF THE OLDER FOSSILIFEROUS TO THE TERTIARY STRATA.

That land as well as sea existed at each successive period — Some former continents placed where it is now sea—Secondary fresh-water deposits, why rare (p. 320.)—Persistency of mineral composition, why apparently greatest in older rocks—Supposed universality of red marl formations — Secondary rocks, why more consolidated — why more fractured and disturbed (p. 325.) — Secondary volcanic rocks of many different ages.

In the last chapter I stated that no detailed account of the older fossiliferous formations would be attempted in this work, and that I should confine myself almost exclusively to the inquiry how far the rules of interpretation previously adopted for the tertiary groups might be applied to the phenomena of more ancient strata. To this point the following remarks are chiefly directed:—

Position of former continents. — The existence of land as well as sea, at every geological period, is attested by the remains of terrestrial plants imbedded in the deposits of all ages, even the most remote. We find fluviatile shells not unfrequently in the secondary strata, and here and there some fresh-water formations; but the latter are less common than in the tertiary series. For this fact the reader's mind has been prepared, by the views advanced in the third

er respecting the different circumstances under which the secondary and tertiary strata appear to have originated. The secondary, it was suggested, may have been accumulated in an ocean like the Pacific, where coralline and shelly limestones are forming; or in a basin like the bed of the western Atlantic, which may have received, for ages, the turbid waters of great rivers, such as the Amazon and Orinoco, each draining a considerable extent of continent. The *tertiary* deposits, on the other hand, very probably accumulated during the growth of a continent, by successive emergence of new lands, and the uniting together of islands. During such changes, inland seas and lakes would be caused, and their basins afterwards filled up with sediment, and then raised above the level of the waters.

That the greater part of the space now occupied by the European continent was sea when some of the secondary rocks were produced, must be inferred from the wide areas over which several of the marine groups are diffused; but we need not suppose that the quantity of land was less in those remote ages, but merely that its position was very different.

It has been shown that, immediately below the chalk and green-sand, a fluviatile formation, called the Wealden, occurs, which has been ascertained to extend from west to east, about 200 English miles, and from north-west to south-east, about 220 miles, the depth or total thickness of the beds, where greatest, being about 2000 feet.* These phenomena clearly indicate that there was a constant supply in that region, for a long period, of a considerable body of fresh water, such as might be supposed to have drained a continent, or a

* Fitton's Geology of Hastings, p. 58.

large island, containing within it a lofty chain of mountains. Dr. Fitton, in speaking of these appearances, recalls to our recollection that the delta of the newly discovered Quorra, or Niger, in Africa, stretches into the interior for more than 170 miles, and occupies, it is supposed, a space of more than 300 miles along the coast; thus forming a surface of more than 25,000 square miles, or equal to about one half of England.*

If asked where the continent was placed from the ruins of which the Wealden strata were derived, we might be almost tempted to speculate on the former existence of the Atlantis of Plato as true in geology, although fabulous as an historical event. We know that the present European lands have come into existence almost entirely since the deposition of the chalk (see map, Plate II.); and the same period may have sufficed for the disappearance of a continent of equal magnitude, situated farther to the west.

But among the numerous fossils of the ancient delta of the Wealden no remains of mammalia have been detected; whereas we should naturally expect, on examining the deposits recently formed at the mouths of the Quorra, Indus, or Ganges, to find, not only the bones of birds and of amphibious and land reptiles, but also those of the hippopotamus, and other mammalia which frequent the banks of rivers. Mr. Mantell seems to have demonstrated†, that the remains of the animals and plants found fossil in the Wealden have, with the exception of the testacea and other aquatic tribes, been transported for a considerable distance, the stems of the plants being, for the most part, torn

* Fitton, Geol. of Hastings, p. 58., who cites Lander's Travels.
† Geol. of S. E. of England, p. 329.

and intermingled with pebbles of quartz, slate, and jasper; while the bones of lizards, turtles, and fish, are detached from the skeleton, and more or less broken and rolled. But, admitting that these fossils were drifted for many a league, we might fairly expect that, at least, some fragments of mammiferous bones would have reached the delta.

It is certainly a startling proposition to suppose, that a continent covered with vegetation, which had its forests of palms and tree-ferns, and its plants allied to the Dracæna and Cycas, which was inhabited by large saurians, and by birds, was, nevertheless, entirely devoid of land quadrupeds. If the proofs were confined to the Wealden, we might hesitate to lay much stress on mere negative evidence, since extensive deposits of the Eocene period, such as the London clay, have as yet yielded no mammiferous fossils. But when we find the same general absence of mammalia in strata of the Oolitic and Liassic eras, we can hardly refuse to admit that the highest order of quadrupeds was very feebly represented in those ages, when the small Didelphys of Stonesfield was entombed. Some of the bones, indeed, collected by Dr. Buckland from the oolitic series have been pronounced by Cuvier to be cetaceous; but that naturalist has himself remarked how closely the vertebræ of the larger reptiles resemble those of certain dolphins; so that it is highly desirable that the fossils alluded to should be re-examined with great care.*

So far, then, as our present inquiries enable us to judge, there are strong indications that, during the

* Mantell, Geol. of England, p. 282.; and see above, Vol. I. p. 227.

periods of the Wealden, the Oolite, and Lias, there was a large development of the reptilia, at the expense, as it were, both of the cetaceous and terrestrial mammalia.

It may be well, then, to inquire whether this difference in the state of animal life in the northern hemisphere, at these remote periods, is irreconcileable with the notion of the constancy and uniformity of the laws which govern the changes of the organic world. Would the almost entire suppression of one important class of vertebrated animals, and the larger development of another, if fully established on farther investigation, imply that there are no fixed rules according to which the form, structure, and attributes of animals are accommodated to the endless vicissitudes of the earth's surface? Or are the rules, if any, made to endure for a time only, new ones being substituted at each successive period? Or, is it conceivable that the distinct zoological characters of certain secondary groups, as compared to others of the tertiary epoch, may depend on laws as uniform as those which, from one century to another, appear to determine the growth of certain tribes of plants and animals in the arctic, and of others in tropical regions?

In Australia, New Zealand, and many other parts of the southern hemisphere, where the indigenous land quadrupeds are comparatively few and of small dimensions, the reptiles do not predominate in number or size. The deposits formed at the mouth of an Australian river, within the tropics, might contain the bones of only a few small marsupial animals, which, like those of Stonesfield, might heafter be discovered with difficulty by geologists; but there would, at the same time, be no megalosauri and other fossil remains, show-

ing that large saurians were plentiful on the land and in the waters when mammalia were scarce.

No precise analogy, therefore, can here be found to the state of the animal kingdom supposed to have prevailed during the secondary periods when a high temperature pervaded European latitudes. But it may be useful to consider whether any of the anomalies now caused by climate in the relative number and importance of different classes of the vertebrata may not in some degree illustrate this topic. In the Arctic regions, for example, reptiles are small, and sometimes wholly wanting, where birds, large land quadrupeds, and cetacea abound. We meet with bears, wolves, foxes, musk oxen, and deer, walrusses, seals, whales, and narwals, in regions of ice and snow, where the smallest snakes, efts, and frogs are rarely if ever seen.

On what grand laws in the animal physiology this remarkable phenomenon depends cannot, in the present state of science, be explained; nor could we predict whether any opposite condition of the atmosphere in respect to heat, moisture, and other circumstances, would bring about a state of animal and vegetable life which might be called the converse of that above described. We ought, however, to recollect, that a mean annual temperature like that now experienced at the equator, co-existing with the unequal days and nights of European latitudes, and with a distinct distribution of sea and land, would imply a climate to which we have now no parallel. Consequently, the type of animal and vegetable existence required for such a climate might deviate as widely from that now established in any part of the globe, as do the Flora and Fauna of our tropical differ from those of our arctic regions.

Secondary fresh-water deposits, why rare. — If there were extensive tracts of land in the secondary period, we may presume that there were lakes also; yet I am not aware of any pure lacustrine formations inter-stratified with rocks older than the chalk. Perhaps their general absence may be accounted for by the adoption of the theoretical views above set forth; for if the present ocean coincides for the most part with the site of the ancient continent, the places occupied by lakes must have been submerged. It should also be recollected, that the area covered by lakes, at any one time, is very insignificant in proportion to the ocean; and, therefore, we may expect that, after the earth's surface has undergone considerable revolutions in its physical geography, the lacustrine strata will be concealed, for the most part, under superimposed marine deposits.

Persistency of mineral character. — In the same manmer as it is rare and difficult to find ancient lacustrine strata, so also we can scarcely expect to discover newer marine groups preserving the same lithological characters continuously throughout wide areas. The chalk now seen stretching for thousands of miles over different parts of Europe has become visible to us by the effect, not of one, but of many distinct series of movements. Time has been required, and a succession of geological periods, to raise it above the waves in so many regions; and if calcareous rocks of the Eocene or Miocene periods have been formed, preserving a homogeneous mineral composition throughout equally extensive regions, it may require convulsions as numerous as all those which have occurred since the origin of the chalk to bring them up within the sphere of human observation. Hence the rocks of more modern

periods may appear of partial extent, as compared to those of remoter eras, not because there was any original difference of circumstances throughout the globe when they were formed, but because there has not been sufficient time for the development of a great series of subterranean volcanic operations since their origin.

At the same time, the reader should be warned not to place implicit reliance on the alleged persistency of the same mineral characters in secondary rocks.* When it was first ascertained that an order of succession could be traced in the principal groups of strata above enumerated, names were given to each, derived from the mineral composition of the rocks in those parts of Germany, England, or France, where they happened to be first studied. When it was afterwards acknowledged that the zoological and phytological characters of the same formations were far more persistent than their mineral peculiarities, the older names were still retained, instead of being exchanged for others founded on more constant and essential characters. The student was given to understand that the terms chalk, green-sand, oolite, red marl, coal, and others, were to be taken in a liberal and extended sense; that chalk was not always a cretaceous rock, but in some places, as on the northern flanks of the Pyrenees, and in Catalonia, a saliferous red marl. Green-sand, it was said, was rarely green, and frequently not arenaceous, but represented in parts of the south of Europe by a hard dolomitic limestone. In like manner, it was declared that the oolitic texture was rather an exception to the general rule in rocks of the oolitic

* See some remarks on this subject, Vol. I. p. 132.

period, and that no particle of carbonaceous matter could often be detected in the true *coal* formation of many districts where it attains great thickness. It must be obvious to every one, that inconvenience and erroneous prepossessions could hardly fail to arise from such a nomenclature; and accordingly a fallacious mode of reasoning has been widely propagated, chiefly by the influence of a language so singularly inappropriate.

After the admission that the identity or discordance of mineral character was by no means a sure test of agreement or disagreement in the age of rocks, it was still thought, by many geologists, that if they found a rock at the antipodes agreeing precisely in mineral composition with another well known in Europe, they could fairly presume that both are of the same age, *until the contrary could be shown.*

Now, it is usually difficult or impossible to combat such an assumption on geological grounds, so long as we are imperfectly acquainted with the geology of a distant country, inasmuch as there are often no organic remains in the foreign stratum; and even if these abound, and are specifically different from the fossils of supposed European equivalent, it may be objected that the we cannot expect the same species to have inhabited very distant quarters of the globe at the same time.

Supposed universality of red marl. — I shall select a remarkable example of the erroneous mode of generalizing now alluded to. A group of red marl and sandstone, sometimes containing salt and gypsum, is found in England interposed between the lias and the carboniferous strata. For this reason, other red marls and sandstones, associated some of them with salt, and

others with gypsum, and occurring not only in different parts of Europe, but in Peru, India, the salt deserts of Asia, those of Africa, in a word, in every quarter of the globe, have been referred to one and the same period. The burden of proof is not supposed to rest with those who insist on the identity of age of all these groups; so that it is in vain to urge as an objection the improbability of the hypothesis which would imply that all the moving waters on the globe were once simultaneously charged with sediment of a red colour.

The absurdity of pretending to identify, in age, all the red sandstones and marls in question, has at length been sufficiently exposed, by the discovery that, even in Europe, they belong decidedly to many different epochs. We have already ascertained, that the red sandstone and red marl, with which the rock-salt of Cardona is associated, may be referred to the period of our chalk and green-sand. I was led to this opinion when I visited Cardona in 1830, and before I was aware that M. Dufrénoy had arrived at the same conclusions.* I have pointed out that in Auvergne there are red marls and variegated sandstones, which are undistinguishable in mineral composition from the new red sandstone of English geologists, yet which were deposited in the Eocene period: and, lastly, the gypseous red marl of Aix, in Provence, formerly supposed to be a marine secondary group, is now acknowledged to be a tertiary fresh-water formation.

Secondary rocks, why more consolidated. — One of the points where the analogy between the secondary and tertiary formations has been supposed to fail, is the greater degree of solidity observable in the secondary

* Ann. des Sci. Nat., Avril, 1831, p. 449.

s e ris. Undoubtedly the older rocks, in general, are more stony than the newer; and most of the tertiary strata are more loose and incoherent in their texture than the secondary. Many exceptions, however, may be pointed out, especially in those calcareous and siliceous deposits which have been precipitated in great part from the waters of mineral springs, and have been originally compact. Of this description are a large proportion of the Parisian Eocene rocks, which are more stony than most of the English secondary groups.

But strata in general have evidently been consolidated *subsequently to their deposition* by a slow lapidifying process. Thus loose sand and gravel are bound together by waters holding carbonate and oxide of iron, carbonate of lime, silica, and other ingredients in solution. These waters percolate slowly the earth's crust in different regions, and often remove gradually the component elements of fossil organic bodies, substituting other substances in their place. It seems, moreover, that the draining off of the waters during the elevation of land may often cause the *setting* of particular mixtures, in the same manner as mortar hardens when desiccated, or as the recent soft marl of Lake Superior becomes highly indurated when exposed to the air.* The conversion of clay into shale, and of sand into sandstone, may, in many cases, be attributed to simple pressure, produced by the weight of superincumbent strata, or by the upward heaving of subjacent masses during earthquakes. Heat is another cause of a more compact and crystalline texture, which will be considered when I speak of the strata termed "primary." All the changes produced by these various

* Vol. I. p. 340.

means require *time* for their completion; and this may explain, in a satisfactory manner, why the older rocks are most consolidated, without entitling us to resort to any hypothesis respecting an *original* distinctness in the degree of lapidification of the secondary strata.

Secondary, why more disturbed. — As the older formations are generally more stony, so also they are more fractured, curved, elevated, and displaced, than the newer. Are we, then, to infer, with some geologists, that the disturbing forces were more energetic in remoter ages? No conclusion can be more unsound; for as the moving power acts from below, the newer strata cannot be deranged without the subjacent rocks participating in the movement; while we have evidence that the older have been frequently shattered, raised, and depressed, again and again, before the newer rocks were formed. It is evident that if the disturbing power of the subterranean causes be exerted with *uniform* intensity in each succeeding period, the quantity of convulsion undergone by different groups of strata will generally be great in proportion to their antiquity. But exceptions will occur, owing to the partial operation of the volcanic forces at particular periods; so that we sometimes find tertiary strata more elevated and disturbed, in particular countries, than the secondary rocks in others.

Some of the enormous faults and complicated dislocations of the ancient strata may probably have arisen from the continued repetition of earthquakes in the same place, and sometimes from two distinct series of convulsions, which have forced the same masses in different, and even opposite directions; sometimes by vertical, at others by horizontal movements.

Secondary volcanic rocks of different ages. — The association of volcanic rocks with different secondary strata is such as to prove that there were igneous eruptions at many distinct periods, as also that they were confined during each epoch, as now, to limited areas. Thus, for example, igneous rocks contemporaneous with the carboniferous strata abound in some countries, but are wanting in others. So it is evident that the bottom of the sea, on which the oolite and its contemporary deposits were thrown down, was, for the most part, free from submarine eruptions; but at some points, as in the Hebrides, it seems that the same ocean was the theatre of volcanic action. It was before remarked*, that, as the ancient eruptions occurred in succession, sufficient time usually intervening between them to allow of the accumulation of many subaqueous strata, so also should we infer that subterranean movements, which are another portion of the volcanic phenomena, occurred separately and in succession.

* Book i. chap. v.

CHAPTER XXV.

RELATIVE ANTIQUITY OF MOUNTAIN-CHAINS.

Theory of M. Elie de Beaumont — His opinions controverted — His method of proving that different chains were raised at distinct periods, and that the rise of others was contemporaneous, not conclusive — His doctrine of the parallelism of contemporaneous lines of elevation — Objections (p. 333.) — How far anticlinal lines formed at the same period are parallel — Difficulties in the way of determining the relative age of mountains.

THAT the different parts of our continents have been elevated, in succession, to their present height above the level of the sea, is an opinion which has been gradually gaining ground with the progress of science; but no one before M. Elie de Beaumont had the merit even of attempting to collect together the recorded facts which bear on this subject, and to reduce them to one systematic whole. The above-mentioned geologist was eminently qualified for the task, as one who had laboured industriously in the field of original observation, and who combined an extensive knowledge of facts with an ardent love of generalization.

But, as I cannot admit the accuracy of an important part of his method of reasoning on this topic, and as his principal conclusions appear to me very uncertain, I must explain the reasons of my dissent, having first given a brief summary of the most prominent features of his theory.

1st. M. de Beaumont supposes, "that in the history of the earth there have been long periods of comparative repose, during which the deposition of sedimentary matter has gone on in regular continuity; and there have also been short periods of paroxysmal violence, during which that continuity was broken.

"2dly. At each of these periods of violence or 'revolution' in the state of the earth's surface, a great number of mountain-chains have been formed suddenly.

"3dly. All the chains thrown up by a particular revolution have one uniform direction, being parallel to each other within a few degrees of the compass, even when situated in remote regions; but the chains thrown up at different periods have, for the most part, different directions.

"4thly. Each 'revolution,' or, as it is sometimes termed, 'frightful convulsion,' has fallen in with the date of another geological phenomenon; namely, 'the passage from one independent sedimentary formation to another,' characterized by a considerable difference in 'organic types.'

"5thly. There has been a recurrence of these paroxysmal movements from the remotest geological periods; and they may still be reproduced, and the repose in which we live may hereafter be broken by the sudden upthrow of another system of parallel chains of mountains.

"6thly. We may presume that one of these revolutions has occurred within the historical era, when the Andes were upheaved to their present height; for that chain is the best defined and least obliterated feature observable in the present exterior configuration of the globe, and was probably the last elevated.

"7thly. The instantaneous upheaving from the ocean of great mountain masses must cause a violent agitation in the waters; and the rise of the Andes may, perhaps, have produced that transient deluge which is noticed among the traditions of so many nations.

"Lastly. The successive revolutions above mentioned cannot be referred to ordinary volcanic forces, but may depend on the secular refrigeration of the heated interior of our planet."*

I need not enter here into an examination of all these topics, as the discussion of several of them has been in some degree anticipated in former chapters. Respecting the alternation of periods of general repose and disorder, I have before suggested that geological phenomena indicate merely that each region of the globe has in succession been a great theatre of subterranean convulsions, as some districts are now, while others remain at rest. Before we can reasonably attribute extraordinary energy to any known cause, we must be sure that its usual force would be inadequate, though exerted for indefinite ages, to produce the effects required.

The geologist, therefore, who assumes that continents and mountain-chains have been heaved up suddenly by paroxysmal violence, may be considered as pledging himself to the opinion that the accumulated effects of ordinary volcanic forces could never in any series of years produce appearances such as we witness in the earth's crust. Time and the progress of

* Ann. des Sci. Nat., Septembre, Novembre, et Décembre, 1829. Revue Française, No. 15. May, 1830. The last edition by M. de B. is in De la Beche's Manual, 3d. edit.; and D'Aubuisson, Traité de Géognosie, tom. iii. p. 282., 1835.

science can alone decide whether such an assumption is warranted, or whether, on the contrary, it does not spring from two sources of prejudice: — first, the difficulty of conceiving the aggregate results of a great number of minor convulsions; secondly, the habit of viewing geological phenomena without any desire to explain them as the effects of moderate forces, such as we know to act, instead of that intense degree of energy, the occasional development of which, however possible, is entirely conjectural.

The speculation of M. de Beaumont concerning the "secular refrigeration" of the internal nucleus of the globe, considered as a cause of the instantaneous rise of mountain-chains, appears to me obscure, and is mainly founded on that part of the doctrine of central heat which has been controverted in the second volume.*

In regard to the connection of the rise of mountain-chains with revolutions equally sudden in the animate world, I have endeavoured to show, in the third book, that changes in physical geography, which are unceasingly in progress, are among the causes which contribute, in the course of ages, to the extermination of certain species of animals and plants; but the influence of these causes is slow, and, for the most part, indirect, and has no analogy with those sudden catastrophes which are introduced into the theory now under review. An explanation of the probable cause of the abrupt transitions from one set of strata to another, containing distinct organic remains, has been given at length in the third and fourth chapters of this book.†

* Book ii. chapters xviii. and xix.

† See particularly from p. 367. to p. 377. of Vol. III.

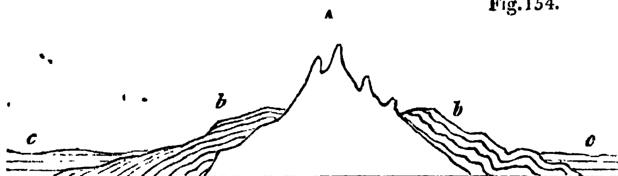
When the protrusion of the Andes from beneath the sea is proposed as a possible cause of the historical deluge, we naturally inquire, what proofs there are of that chain having started up at once within the last 4000 or 5000 years from a great depth of sea; for it is necessary that a large body of water should be displaced, in order that a diluvial wave, capable of inundating a previously existing continent, should be raised. If it were reasonable to refer deluges to what have been called paroxysmal elevations, it would surely be a fairer speculation to point to a line of shoals or reefs, consisting of shattered and dislocated rocks, and surrounded on all sides by an unfathomable ocean, than to select a mountain-chain as the site of the upthrow; for the rapid conversion of the bed of a deep sea into a shoal would evidently cause a much greater displacement of water than the rise of a large shoal into a mountain-chain.

Without dilating further on these subjects, I shall now endeavour to analyze the proofs by which the successive elevation of different chains, and the supposed parallelism of lines of contemporaneous elevation, are supported.

M. de Beaumont's proofs that different chains were raised at different epochs.—"We observe," says M. Elie de Beaumont, "along nearly all the mountain-chains, when we attentively examine them, that the most recent rocks extend horizontally up to the foot of such chains, as we should expect would be the case if they were deposited in seas or lakes, of which these mountains have partly formed the shores; whilst the other sedimentary beds tilted up, and more or less contorted, on the flanks of the mountains, rise in cer-

tain points even to their highest crests."* There are, therefore, in and adjacent to each chain, two classes of sedimentary rocks, the ancient or inclined beds, and the newer or horizontal. It is evident that the first appearance of the chain itself was an event "intermediate between the period when the beds now upraised were deposited and that when the strata were produced horizontally at its feet."

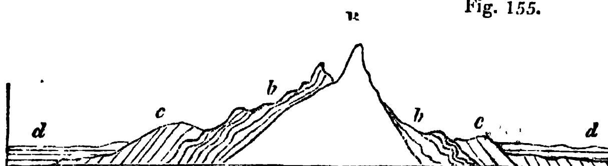
Fig. 154.



Thus the chain A assumed its present position after the deposition of the strata *b*, which have undergone great movements, and before the deposition of the group *c*, in which the strata have not suffered derangement.

If we then discover another chain, B, in which we

Fig. 155.



find not only the formation *b*, but the group *c* also, disturbed and thrown on its edges, we may infer that the latter chain is of subsequent date to A; for B must have been elevated *after* the deposition of *c*, and before that of the group *d;* whereas A had originated *before* the strata *c* were formed.

* Phil. Mag. and Annals, No. 58., New Series, p. 242.

In order to ascertain whether other mountain ranges are of contemporaneous date with A and B, or are referrible to *distinct* periods, we have only to inquire whether the geological phenomena are identical; namely, whether the inclined and undisturbed sets of strata in each correspond to those in the types above mentioned.

Objections to M. de Beaumont's theory. — Now all this reasoning is perfectly correct, so long as the periods of the deposition of the particular local groups, of strata *b* and *c* are not confounded with the periods during which the animals and plants found fossil in *b* and *c* may have flourished, and provided also that due latitude is given to the term contemporaneous; for this term must be understood to allude, not to a moment of time, but to the interval, whether brief or protracted, which elapsed between two events, namely, between the accumulation of the inclined and that of the horizontal strata.

But, unfortunately, no attempt seems to have been made to avoid this manifest source of confusion, and hence the very terms of each proposition are equivocal; and the length of some of the intervals is so vast, that to affirm that all the chains raised in such intervals were *contemporaneous*, is an abuse of language.

In order to illustrate this argument, I shall select the Pyrenees as an example. This range of mountains, says M. de Beaumont, rose suddenly (à un seul jet*) to its present elevation at a certain epoch in the

* In the last edition of M. de B.'s system (see note above, p. 329.), he only speaks of the convulsion which raised the Pyrenees, as "one of the most violent which the land of Europe ever experienced."

earth's history, namely, between the deposition of the chalk and that of the tertiary formations; for the chalk is seen in vertical, curved, and distorted beds on the flanks of the chain, while the tertiary formations rest upon them in horizontal strata at its base.

The only proof offered of the extreme suddenness of the convulsion is the shortness of the time which intervened between the formation of the chalk and that of the tertiary strata.*

Now the beds called chalk on the flanks of the Pyrenees differ widely in mineral composition from the white chalk with flints of England and France; but as they contain for the most part the same species of fossil shells, I grant that they may on that evidence be referred to the cretaceous system.† On the other hand, the horizontal tertiary strata at the western end of the Pyrenees, near Bayonne, are certainly of the Miocene period. The reader will find, when he reflects on these data, that we can only infer that the great movement took place after the cretaceous period had commenced, but we cannot assume that it occurred after the *close* of that period. So also we may say, that the Pyrenees rose before the close of the Miocene epoch, but not that the event happened before its *commencement*. We cannot permit M. de Beaumont to exclude the whole of either of these periods (the Cretaceous and Miocene) from the possible duration of that interval during all or any part of which the elevation may have taken place.

* Phil. Mag. and Annals, No. 58., New Series, p. 243.

† The fossils which I collected in company with Captain S. E. Cook, R. N., from the newest secondary beds on the flanks of the Pyrenees, near Bayonne, were examined by M. Deshayes, and found identical with species of the chalk near Paris.

The upheaving of the Pyrenees, therefore, may have been going on before the animals of the chalk period ceased to exist, or when the Maestricht beds were in progress, or during the indefinite ages which may have elapsed between the extinction of the Maestricht animals and the introduction of the Eocene tribes, or during the Eocene epoch, or between that and the Miocene, or at the commencement of the Miocene epoch. Or the rise may have been going on throughout one, or several, or all of these periods.

It would be a purely gratuitous assumption to say that the chalk strata *c*, Fig. 155., p. 332., were the last which were deposited during the cretaceous period, or that, when they were upheaved, all or nearly all the species of animals and plants which are now found fossil in them were suddenly exterminated: yet, unless this can be affirmed, we cannot say that the chain B was not upheaved during the cretaceous period. Consequently, another range of mountains (A, Fig. 154.), at the base of which cretaceous rocks, *c*, may lie in horizontal stratification, may have been elevated during the same period; because, in this case, the particular group *c* may have been formed long after the animals and plants which are characteristic of them, in a fossil state, began to flourish, and during those antecedent ages the chain A may have risen.

The Newer Pliocene strata in Sicily have been raised to the height of nearly 3000 feet in some places, with great derangement; yet the testacea and zoophytes inclosed in these still exist, or nine tenths of them at least, in the Mediterranean. The same period still continues, if we speak of periods in the same extended sense in which they are understood by geologists, and by M. de Beaumont, in the memoir now

before us. So the chalk in the Pyrenees may have been raised to the height of many thousand feet, when the animals found fossil in the upheaved strata still continued to inhabit the sea.

In like manner the sea may have been inhabited by Miocene testacea for ages before the deposition of those particular Miocene strata which occur at the foot of the Pyrenees.

To illustrate the grave objections above advanced, which go to affect the whole of De Beaumont's reasoning, let us suppose, that in some country three styles of architecture had prevailed in succession, each for a period of one thousand years; first the Greek, then the Roman, and then the Gothic; and that a tremendous earthquake was known to have occurred in the same district during some part of the three periods,—a shock of such violence as to have levelled to the ground all the buildings then standing. If an antiquary, desirous of discovering the date of the catastrophe, should first arrive at a city where several Greek temples were lying in ruins and half engulphed in the earth, while many Gothic edifices were standing uninjured, could he determine on these data the era of the shock? Certainly not. He could merely affirm that it happened at some period after the introduction of the Greek style, and before the Gothic had fallen into disuse. Should he pretend to define the date of the convulsion with greater precision, and decide that the earthquake must have occurred in the interval between the Greek and Gothic periods, that is to say, when the Roman style was in use, the fallacy in his reasoning would be too palpable to escape detection for a moment.

Yet such is the nature of the erroneous induction

which I am now exposing. For, as in the example above proposed, the erection of a particular edifice is perfectly distinct from the period of architecture in which it may have been raised, so is the deposition of chalk, or any other set of strata, from the geological epochs characterized by certain fossils to which they may belong.

It is superfluous to enter into any farther analysis of this theory, because the force of the whole argument depends on the accuracy of the data by which the contemporaneous or non-contemporaneous date of the elevation of two independent chains can be demonstrated. In every case, this evidence, as stated by M. de Beaumont, is equivocal, because he has not included in the possible interval of time between the deposition of the deranged and the horizontal formations part of the periods to which each of those classes of formations are referrible. By the insufficiency, then, of the above proofs, the doctrine of the parallelism of lines of contemporaneous elevation is destroyed; because all the geological facts may be true, and yet the conclusion that certain chains were or were not simultaneously upraised is by no means a legitimate consequence.

As the hypothesis of parallelism, however, has acquired some popularity, I may remark, that it appears, as stated by the author, to be in some degree at variance with itself. When certain European chains were assumed to have been raised at the same time, on the data already impugned, it was found that several of these contemporaneous chains had a parallel direction. Hence it was immediately inferred to be a general law in geological dynamics that the chains upheaved at the same time are parallel. For example, it was said

that the Pyrenees and northern Apennines have a direction about W. N. W. and E. S. E.; to this line the Alleghanies, in North America, conform, as also the Ghauts of Malabar, and certain chains in Egypt, Syria, northern Africa, and other countries; and from this mere conformity in direction it was presumed that all these mountain-ranges were thrown up simultaneously.*

To select another example, the principal chain of the Alps, differing in age and direction from the Pyrenees, is parallel to the Sierra Morena, the Balkan, the chain of Mount Atlas, the central chain of the Caucasus, and the Himalaya. All these ridges, therefore, are assumed to have been heaved up by the same paroxysmal convulsion. The western Alps, on the other hand, rose at a still earlier period, when the parallel chains of Kiöl, in Scandinavia, certain chains in Morocco, and the littoral Cordillera of Brazil, were formed!

Not only do these speculations refer to mountains never yet touched, as M. Boué remarks, by the hammer of the geologist, but they proceed on the supposition, that in these distant chains the geological and geographical axes always coincide. Now we know that in Europe the *strike* † of the beds is not always parallel to the direction of the chain. As an exception, we

* In regard to the Alleghanies, see De Beaumont, 1833. French Trans. of De la Beche's Manual, p. 657. But in fact this chain runs from N. E. to S. W.

† The term "strike" has been recently adopted by some of our most eminent geologists from the German "streich," to signify what our miners call the "line of bearing" of the strata. Such a term was much wanted; and, as we often speak of *striking* [illegible] a given direction, the expression seems sufficiently consistent [illegible] analogy in our language.

may instance the Hartz mountains, where Von Dechen * states that the direction or *strike* of the strata of slate and greywacké is sometimes from E. and W., and frequently N. E. and S. W.; the geographical direction of the mountain-chain being decidedly from E. S. E. to W. N. W.

In addition to these considerations, the important admission is made by M. de Beaumont himself, that the elevating forces, whose activity must be referred to *different* epochs, have sometimes acted in Europe in *parallel* lines. "It is worthy of remark," he says, "that the directions of three systems of mountains, —namely, first, that of the Pilas and the Côte d'Or; secondly, that of the Pyrenees; and thirdly, that of the islands of Corsica and Sardinia,— are respectively parallel to three other systems, namely, first, that of Westmoreland and the Hunsdruck; secondly, that of the Ballons (or Vosges) and the hills of the Bocage, in Calvados; and thirdly, the system of the north of England. The corresponding directions only differ in a few degrees, and the two series have succeeded each other in the same order, leading to the supposition, that there has been *a kind of periodical recurrence* of the same, or nearly the same, directions of elevations." †

Here then, we have three systems of mountains, A, B, C, which were formed at successive epochs, and have each a different direction; and we have three other systems, D, E, F, which, although they are assumed to have the same strike as the series first mentioned, (D corresponding with A, E with B, and

* Trans. of De la Beche's Geol. Manual, p. 41.

† Phil. Mag. and Annals, No. 58., New Series, pp. 255, 256.

F with C,) are nevertheless declared to have been formed at different periods. On what principle, then, is the age of an Indian or transatlantic chain referred to one of these European lines rather than to another? — why is the age of the Alleghanies, or the Ghauts of Malabar, determined by their parallelism to B rather than to E, to the Pyrenees rather than to the Ballons of the Vosges? *

Modern volcanic lines not parallel. — The analogy of volcanic operations in our own times would lead us to suppose that the lines of convulsion, at former epochs, were far from being uniform in direction; for that the trains of *active* volcanos are not parallel, every one is aware who has studied Von Buch's masterly survey of the general range of volcanic lines over the globe †; while the elevations and subsidences caused by modern earthquakes, although they may sometimes run in parallel lines within limited districts, have not been observed to have a common direction in distant and independent theatres of volcanic action.

I doubt not that in many regions, yet only within a limited range of country, the ridges, troughs, and fissures caused by modern earthquakes are, to a certain extent, parallel to each other; and such appears to have been the case in many districts at former eras.

* The substance of the last objection has been anticipated by M. Boué (Journ. of Geol., tom. iii. p. 338.). I shall not repeat here minor points and facts, enumerated, in a former edition, as disputed by several geologists, because they are of no importance, if the basis of the theory is unfounded. See Mr. Conybeare's remarks, Phil. Mag. and Journ. of Sci., No. 2., Third Series, p. 118. Studer, Bulletin de la Soc. Géol. de France, ii. p. 68.

† Physical. Besch. der Canarischen Inseln. Berlin, 1825.

The anticlinal lines of the Weald valley, before alluded to, and of the Isle of Wight, may, in this manner, have been contemporaneous; that is to say, both may have been formed in some part of the Eocene period,— an hypothesis which does not involve the theory of their having been due to a paroxysmal convulsion at the same moment of that vast period. It should be observed, that, as some trains of burning volcanos are parallel to each other, so at all periods some independent lines of elevation may be parallel *accidentally*; not in obedience to any known law of parallelism; but, on the contrary, as exceptions to the general rule.

The speculations of M. de Beaumont will, I trust, be useful in inducing geologists to inquire how far the uniformity in the direction of the beds, in a region which has been agitated at any particular period, may extend; but, in the present state of our science, I cherish no sanguine expectations of fixing a chronological succession of epochs of elevation of different mountain-chains, or of making more than a loose approximation to such a result. The difficulty depends chiefly on the broken and interrupted nature of the series of sedimentary formations hitherto brought to light, which appears so imperfect that we can very seldom be sure that between the groups now classed as consecutive, the memorials of some great interval of time may not be wanting. Another great source of ambiguity arises from the small progress which we have yet made in identifying strata in countries somewhat distant from each other.

There may be instances, perhaps, where the same set of strata, preserving throughout a perfect identity of mineral character, may be traced continuously from

the flanks of one independent mountain-chain to the base of another, the beds being vertical or inclined in one chain, and horizontal in the other. We might then decide with confidence, according to the method proposed by M. de Beaumont, on the relative periods at which these chains had undergone disturbance; and from one point thus securely established, we might proceed to another, until we had determined the eras of many neighbouring lines of convulsion.

CHAPTER XXVI.

ON THE ROCKS COMMONLY CALLED "PRIMARY."

Relation of rocks called "Primary" to volcanic and sedimentary formations — Unstratified rocks called "Plutonic" — Granite veins — Their various forms and mineral composition — Proofs of their igneous origin — Granites of the same character produced at successive eras (p. 350.) — Some of these newer than certain fossiliferous strata — Volcanic, trappean, and plutonic rocks.

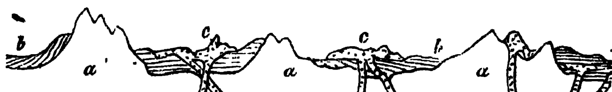
I SHALL now treat of the class of rocks usually termed "primary," a name which, as I shall afterwards show, is not always applicable, since the formations so designated sometimes belong to different epochs, and are not, in every case, more ancient than the fossiliferous strata. In general, however, this division of rocks may justly be regarded as of higher antiquity than the secondary and transition groups above described; and they may, therefore, with propriety be spoken of in these concluding chapters, as I have hitherto proceeded in my retrospective survey from the newer to the more ancient geological monuments.

In order to explain the relation which I conceive the rocks termed "primary" to bear to the tertiary, secondary, and transition formations, I shall resume that general view of the component parts of the earth's crust of which I gave a slight sketch in the preliminary division of the subject in the second chapter.*

* See Vol. III. pp. 335, 336.

It was there stated that sedimentary formations, containing organic remains, occupy a large part of the surface of our continents; but that here and there volcanic rocks occur, covering, alternating with, or breaking through, the sedimentary deposits; so that there are two orders of mineral masses formed at the surface, which have obviously a distinct origin, — the aqueous and the volcanic.

Fig. 156.



a. Formations called primary (stratified and unstratified).
b. Aqueous formations. *c.* Volcanic rocks.

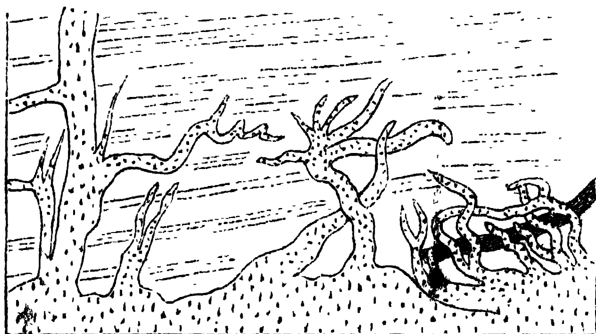
Besides these, however, there is another class, which cannot be assimilated precisely to either of the preceding, and which is often seen underlying the sedimentary, or breaking up to the surface in the central parts of mountain-chains, constituting some of the highest lands, and, at the same time, passing down and forming the inferior parts of the crust of the earth. This class, usually termed "primary," is divisible into two groups,— the stratified and the unstratified. The stratified consists of the rocks called gneiss, mica-schist, argillaceous-schist (or clay-slate), hornblende schist, primary limestone, and some others. The unstratified, or Plutonic, is composed in great measure of granite, and rocks closely allied to granite. Both these groups agree in having, for the most part, a highly crystalline texture, and in not containing organic remains.

Plutonic rocks. — The unstratified crystalline rocks have been very commonly called Plutonic, from the

opinion that they were formed by igneous action at great depths; whereas the volcanic, although they also have risen up from below, have cooled from a melted state upon or near to the surface. Granite, porphyry, and other rocks of the same family, often occur in large amorphous masses, from which small veins and dikes are sent off, which traverse the stratified rocks called "primary," precisely in the manner in which lava is seen in some places to penetrate the secondary strata.

Granite veins. — We find also one set of granite veins intersecting another, and granitiform porphyries intruding themselves into granite, in a manner analogous to that of the volcanic dikes of Etna and Vesuvius, where they cut and shift each other, or pass through alternating beds of lava and tuff.

Fig. 157.



Granite veins traversing stratified rocks.

The annexed diagram will explain to the reader the manner in which these granite veins often branch off from the principal mass. Those on the right-hand side, and in the middle, are taken from Dr. Maccul-

loch's representation of veins passing through the gneiss at Cape Wrath, in Scotland.* The veins on the left of the same diagram are described, by Captain Basil Hall, as traversing the argillaceous schist of the Table-Mountain at the Cape of Good Hope.†

I subjoin another sketch from Dr. Macculloch's interesting representations of the granite veins in Scotand, in which the contrast of colour between the vein



Granite veins traversing gneiss at Cape Wrath, in Scotland.

and some of the dark varieties of hornblende-schist associated with the gneiss renders the phenomena more conspicuous.

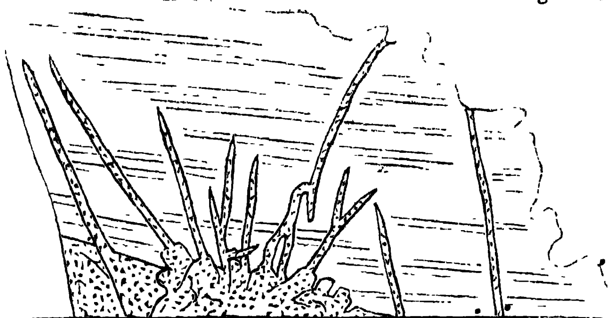
The following sketch of a group of granite veins in Cornwall is given by Messieurs Von Oeynhausen and Von Dechen.‡ The main body of the granite here is of a porphyritic appearance, with large crystals of felspar; but in the veins it is fine-grained, and without these large crystals. The general height of the veins is from sixteen to twenty feet, but some are much higher.

* Western Islands, plate 31.

† Account of the Structure of Table-Mountain, &c. Trans. Roy. Soc. Edin., vol. vii.

‡ Phil. Mag. and Annals, No. 27., New Series, March, 1829.

Fig. 159.



Granite veins passing through hornblende slate, Carnsilver Cove, Cornwall.

The vein-granite of Cornwall very generally assumes a finer grain, and frequently undergoes a change in mineral composition, as is very commonly observed in other countries. Thus, according to Professor Sedgwick, the main body of the Cornish granite is an aggregate of mica, quartz, and felspar; but the veins are sometimes without mica, being a granular aggregate of quartz and felspar. In other varieties quartz prevails to the almost entire exclusion both of felspar and mica; in others, the mica and quartz both disappear, and the vein is simply composed of white granular felspar.*

Changes are sometimes caused in the intersected strata very analogous to those which the contact of a fused mass might be supposed to produce.

The annexed diagram, from a sketch of Dr. Macculloch, represents the junction of the granite of Glen Tilt, in Perthshire, with a mass of stratified limestone

* On Geol. of Cornwall, Trans. of Cambridge Soc., vol. i. p. 124.

and schist. The granite, in this locality, often sends forth so many veins as to reticulate the limestone and schist, the veins diminishing towards their termination to the thickness of a leaf of paper or a thread. In some places fragments of granite appear entangled, as it were, in the limestone, and are not visibly connected with any larger mass; while sometimes, on the other hand, a lump of the limestone is found in the midst of the granite. The ordinary colour of the limestone of

Fig. 160.

Junction of granite and limestone in Glen Tilt.

a. Granite. b. Limestone.
c. Blue argillaceous schist.

Glen Tilt is lead blue, and its texture large-grained and highly crystalline; but where it approximates to

the granite, particularly where it is penetrated by the smaller veins, the crystalline texture disappears, and it assumes an appearance exactly resembling that of horn-stone. The associated argillaceous schist often passes into hornblende slate, where it approaches very near to the granite.*

The conversion of the limestone in these and many other instances into a siliceous rock, effervescing slowly with acids, would be difficult of explanation, were it not ascertained that such limestones are always impure, containing grains of quartz, mica, or felspar disseminated through them. The elements of these minerals, when the rock has been subjected to great heat, may have been fused, and so spread more uniformly through the whole mass.

In the plutonic, as in the volcanic rocks, there is every gradation from a tortuous vein to the most regular form of a dike, such as I have described intersecting the tuffs and lavas of Vesuvius and Etna. In these dikes of granite, which may be seen, among other places, on the southern flank of Mount Battoch, one of the Grampians, the opposite walls sometimes preserve an exact parallelism for a considerable distance. It is not uncommon for one set of granite veins to intersect another; and sometimes there are three sets, as in the environs of Heidelberg, where the granite on the banks of the river Necker is seen to consist of three varieties, differing in colour, grain, and various peculiarities of mineral composition. One of these, which is evidently the second in age, is seen to cut through an older granite; and another, still newer, traverses both the second and the first. These pheno-

* Macculloch, Geol. Trans., vol. iii. p. 259.

mena were pointed out to me by Professor Leonhard at Heidelberg.

In Shetland there are two kinds of granite. One of these, composed of hornblende, mica, felspar, and quartz, is of a dark colour, and is seen underlying gneiss. The other is a red granite, which penetrates the dark variety every where in veins.*

Granites of different ages.—It was formerly supposed that granite was the oldest of rocks, the mineral product of a particular period or state of the earth, formed long antecedently to the introduction of organic beings into our planet. But it is now ascertained that this rock has been produced again and again, at successive eras, with the same characters, penetrating the stratified rocks in different regions, but not always associated with strata of the same age. Nor are organic remains always entirely wanting in the formations invaded by granite, although they are usually absent. Many well authenticated exceptions to the rule are now established, on the authority of numerous observers, amongst the earliest of whom we may cite Von Buch, who discovered in Norway a mass of granite overlying an ancient secondary limestone, containing orthocerata and other shells and zoophytes.†

A considerable mass of granite in the Isle of Sky is described by Dr. Macculloch as incumbent on limestone and shale, which are of the age of the English lias.‡ The limestone, which, at a greater distance from the granite, contains shells, exhibits no traces of

* Macculloch, Syst. of Geol., vol. i. p. 58.

† Travels through Norway and Lapland, p. 45. London, 1813.

‡ See Murchison, Geol. Trans., Second Series, vol. ii. part ii. p. 311—321.

them near its junction, where it has been converted into a pure crystalline marble.*

This granite of Sky was at first termed "Syenite," by which name some authors have denominated the more modern granites; but they have entirely failed in their attempt to establish a distinction between granites and syenites on geological grounds. Syenite has been defined to be a triple compound of felspar, quartz, and hornblende; but the oldest granitiform rocks are very commonly composed of these ingredients only. In his later publications Dr. Macculloch has, with great propriety, I think, called the plutonic rock of Sky a granite.†

In different parts of the Alps a comparatively modern granite is seen penetrating through secondary strata, which contain belemnites, and other fossils, and are supposed to be referrible to the age of the English lias. According to the observations of MM. Elie de Beaumont and Hugi, masses of this granite are sometimes found partially overlying the secondary beds, and altering them in a manner analogous to the changes superinduced upon sedimentary deposits in contact with rocks of igneous origin.‡ (See Fig. 163. p. 376.)

In such examples we can merely affirm, that the granite is newer than a secondary formation containing belemnites; but we can form no conjecture when it originated, not even whether it be of secondary or tertiary date. It is not to be inferred that a granite is

* Western Islands, vol. i. p. 330.

† Syst. of Geol., vol. i. p. 150.

‡ Elie de Beaumont, sur les Montagnes de l'Oisans, Mém. de la Soc. d'Hist. Nat. de Paris, tome. v. Hugi, Natur. Historische Alpenreise, Soleure, 1830.

usually of about the same age as the group of strata into which it has intruded itself; for in that case we should be inclined to assume, rashly, that the granite found penetrating a more modern rock, such as the lias, for example, was much newer than that which is found to invade greywacké. The contrary may often be true; for the plutonic rock which was last in a melted state may not anywhere have been forced up so near to the surface as to traverse the newer groups, but may be confined exclusively to the older sedimentary formations.

"In a deep series of strata," says Dr. Macculloch, "the superior or distant portions may have been but slightly disturbed, or have entirely escaped disturbance, by a granite which has not emitted its veins far beyond its immediate boundary. However certain, therefore, it may be, that any mass of granite is posterior to the gneiss, the micaceous schist, or the argillaceous schists, which it traverses, or into which it intrudes, we are unable to prove that it is not also posterior to the secondary strata that lie above them."*

There can be little doubt, however, that some granites are more ancient than any of our regular series which we identify by organic remains; because there are rounded pebbles of granite, as well as gneiss, in the conglomerates of very ancient fossiliferous groups.

Distinction between volcanic and plutonic rocks — Trap. — When geologists first began to examine attentively the structure of the northern parts of Europe, they were almost entirely ignorant of the phenomena of existing volcanos; and when they met with basalt

* Syst. of Geol., vol. i. p. 136.

and other rocks composed chiefly of augite, hornblende, and felspar, which are now admitted by all to have been once in a state of fusion, they were divided in opinion whether they were of igneous or of aqueous origin. In the sketch of the history of geology in the first volume, it was shown how much the polemical controversies on this subject retarded the advancement of the science, and how slowly the analogy of the rocks in question to the products of active volcanos was recognized.

Most of the igneous rocks first investigated in Germany, France, and Scotland were associated with marine strata, and in some places they occurred in tabular masses or platforms at different heights, so as to form on the sides of some hills a succession of terraces or *steps;* from which circumstance they were called "trap" by Bergman (from *trappa*, Swedish for a flight of steps),—a name afterwards adopted very generally into the nomenclature of the science.

When these trappean rocks were compared with lavas produced in the atmosphere, they were found to be in general less porous and more compact; and from this character, and their association with subaqueous deposits, the connection of their origin with ordinary volcanic action was overlooked. In this instance the terms of comparison were imperfect; for a set of rocks, formed almost entirely under water, was contrasted with another which had cooled in the open air.

Yet the products of the ancient volcanos of Central France were classed, in reference, probably, to their antiquity, with the trap rocks, although they afford perfect counterparts to existing volcanos, and were evidently formed in the open air. Mont Dor and the Plomb du Cantal, indeed, differ in many respects from

Vesuvius and Etna in the mineral constitution and structure of their lavas; but it is that kind of difference which we must expect to discover when we compare the products of any two active volcanos in distant regions, such as Teneriffe and Hecla, or Hecla and Cotopaxi.

The amygdaloidal structure in many of the trap formations proves that they were originally cellular and porous, like lava; but the cells have been subsequently filled up with silex, carbonate of lime, zeolite, and other ingredients which form the nodules. The absence of this amygdaloidal structure may be said to be one of the negative characters of granite and other plutonic rocks.

Dr. Macculloch, after examining with great attention the igneous rocks of Scotland, observes, "that it is a mere dispute about terms to refuse to the ancient eruptions of trap the name of submarine volcanos, for they are such in every essential point, although they no longer eject fire and smoke."* The same author also considers it not improbable that some of the volcanic rocks of the same country may have been poured out in the open air.†

The recent examination of the igneous rocks of Sicily, especially those of the Val di Noto, has proved that all the more ordinary varieties of European trap have been produced under the waters of the sea in the Newer Pliocene period; that is to say, since the Mediterranean has been inhabited by a great proportion of the existing species of testacea. We are, therefore, entitled to expect, that if we could obtain access to the existing bed of the ocean, and explore the igneous

* Syst. of Geol., vol. ii. p. 114. † Ibid.

rocks poured out within the last five thousand years beneath the pressure of a sea of considerable depth, we should behold formations of modern date very similar to the most ancient trap rocks of our island. We cannot, however, expect the identity to be perfect; for time is ever working some alteration in the composition of these mineral masses, as, for example, by converting porous lava into amygdaloids.

Passage from trap into granite. — If a division be attempted between the trappean and volcanic rocks, it must be made between different parts of the same volcano, — nay, even the same rock, which would be called "trap," where it fills a fissure and has assumed a solid crystalline form on slow cooling, must be termed volcanic, or lava, where it issues on the flanks of the mountain. Some geologists may, perhaps, be of opinion that melted matter, which has been poured out in the open air, may be conveniently called volcanic; while that which appears to have cooled at the bottom of the sea, or under pressure, but at no great depth from the surface, may be termed "trap:" but it is very doubtful whether such distinctions can be made without confusion, and whether we shall not be obliged to consider trap and volcanic as synonymous. On the other hand, the difficulty of discriminating the volcanic from the plutonic rocks is sufficiently great; there being an insensible passage from the most common forms of granite into trap or lava.

"The ordinary granite of Aberdeenshire," says Dr. Macculloch, "is the usual ternary compound of quartz, felspar, and mica; but sometimes hornblende is substituted for the mica. But in many places a variety occurs which is composed simply of felspar and hornblende; and in examining more minutely this

duplicate compound, it is observed in some places to assume a fine grain, and at length to become undistinguishable from the greenstones of the trap family. It also passes in the same uninterrupted manner into a basalt, and at length into a soft claystone, with a schistose tendency on exposure, in no respect differing from those of the trap islands of the western coast." * The same author mentions, that in Shetland a granite composed of hornblende, mica, felspar, and quartz graduates in an equally perfect manner into basalt. †

It would be easy to multiply examples to prove that the granitic and trap rocks pass into each other, and are merely different forms which the same elements have assumed, according to the different circumstances under which they have consolidated from a state of fusion. What has been said respecting the mode of explaining the different texture of the central and external parts of the Vesuvian dikes may enable the reader in some measure to comprehend how such differences may originate. ‡

The lavas, which are porous where they have flowed over the crater, and cooled rapidly under comparatively slight pressure, appear compact and porphyritic in the dike. Now these dikes evidently communicate with the crater and the volcanic foci below; so that we may suppose them to be continuous to a vast depth; and the fluid matter below, which cools and consolidates slowly under so enormous a pressure, may be conceived to acquire a very distinct and more crystalline texture, like granite.

If it be objected that we do not find in mountain-

* Syst. of Geol., vol. i. p. 157. † Ibid., p. 158.
‡ See p. 23.

chains volcanic dikes passing upwards into lava, and downwards into granite, we may answer, that our vertical sections are usually of small extent; and if we find in certain places a transition from trap to porous lava, and in others a passage from granite to trap, it is as much as could be expected of this evidence. It should also be remembered, that a large proportion of the igneous rocks, when first formed, cannot be supposed to reach the surface, and these may assume the usual granitic texture without graduating into trap, or into such lava and scoriæ as are found on the flanks of a volcanic cone.

Theory of the origin of granite at all periods. — It is not uncommon for lava streams to require more than ten years to cool in the open air; and where they are of great depth, a much longer period. The melted matter poured from Jorullo, in Mexico, in the year 1759, which accumulated in some places to the height of 550 feet, was found to retain a high temperature half a century after the eruption.* For what immense periods, then, may we not conceive that great masses of subterranean lava in the volcanic foci may remain in a red-hot or incandescent state, and how gradual must be the process of refrigeration! This process may be sometimes retarded for an indefinite period, by the accession of fresh supplies of heat; for we find that the lava in the crater of Stromboli, one of the Lipari islands, has been in a state of constant ebullition for the last two thousand years; and we must suppose this fluid mass to communicate with some cauldron or reservoir of fused matter below. In the Isle of Bourbon, also, where there has been an emission of lava once in

* See Vol. II. p. 187.

every two years for a long period, we may infer that the lava below is permanently in a state of liquefaction.

The great pressure of a superincumbent mass, and exclusion from contact with the atmosphere, and perhaps with the ocean, are some of the conditions which may be necessary to produce the granitic texture; but what I have before said of the causes of volcanic heat operating at considerable depths, will show how complicated may be the processes going on in the interior of the earth, and how different from any within the sphere of our observation at the surface.*

If plutonic rocks, such as granite or porphyry, have originated far below as often as the volcanic have been generated at the surface, it will follow that no small quantity of the former class has been forming in the recent epoch; since we suppose that about two thousand volcanic eruptions may occur in the course of every century, either above the waters of the sea or beneath them.†

We may also infer, that during each preceding period, whether tertiary or secondary, there have been granites and granitiform rocks generated; because we have already discovered the monuments of ancient volcanic eruptions of almost every period.

In the next chapter I shall endeavour to show, that, in consequence of the great depths at which the plutonic rocks usually originate, and of the manner in which they are associated with the older sedimentary strata of each district, it is rarely possible to determine with exactness their relative age. It may be true that the greater portion of them now visible are of higher

* Book ii. chapters 18. and 19. † See Vol. II. p. 224.

antiquity than the oldest secondary strata; and yet they may have been produced in nearly *equal* quantities during *equal periods* of time, from the earliest to the most modern epochs, instead of diminishing in quantity at each successive epoch, as some geologists pretend.

CHAPTER XXVII.

ON THE STRATIFIED ROCKS CALLED "PRIMARY."

Whether any "primary" rocks are truly stratified — Difference between stratification and cleavage — Professor Sedgwick on the Slaty and the Jointed Structure — Alteration of sedimentary strata by dikes (p. 371.) — Manner in which heat may be conveyed through rocks — Conversion of sedimentary into crystalline strata — The term "Hypogene" proposed as a substitute for "primary" (p. 385.)— "Metamorphic" for "stratified primary" rocks — No regular order of succession of hypogene rocks — Cause of the high relative antiquity of visible hypogene formations (p. 390.) — They may have been produced at each successive period in equal quantities — Volume of hypogene rocks supposed to have been formed since the Eocene period — Concluding remarks.

Whether any primary rocks are stratified.—It has been stated that the rocks usually called "Primary," are divisible into the stratified and the unstratified; but some geologists have entertained doubts as to the propriety of applying the term stratified to any rocks of the crystalline or "primary" class. They admit that the latter are often made up of tabular masses, or beds placed one upon the other, something in the manner of true strata; but they deny that the analogy is so perfect as to indicate a similarity of origin: in other words, they do not believe the distinct beds into which crystalline rocks, such as gneiss, mica-schist, and hornblende-schist, are divided, to have been the result of sedimentary deposition from water.

Now it must be conceded that even in rocks which are unequivocally of sedimentary origin, and which contain organic remains, there are many lines of parting that might easily be mistaken for strata, yet which have no connection with stratification. Of these partings some have been distinguished by miners under the name of "joints," others by that of the "planes of cleavage."

Cleavage or slaty structure. — In an admirable essay recently published on this subject, Professor Sedgwick has described the ordinary forms, and speculated on the probable origin, of these different kinds of structure.* His descriptions are derived from an extensive series of original observations, made on the slate rocks of Cumberland and Wales, and will be read by all who are desirous of obtaining a clear and thorough knowledge of this important class of phenomena.

Some of these Cumbrian and Welsh rocks are decidedly of mechanical origin; and some strata contain marine organic remains, so that they must have been deposited from water. But besides being stratified, they are intersected by cleavage planes, which are usually inclined at a very considerable angle to the planes of the strata, and appear to be in no instance exactly coincident with them. In some cases the difference is so small that these planes might easily be supposed parallel; but their inclination to each other in the Welsh chains, is upon an average as much as 30° to 40°. Sometimes the cleavage planes dip towards the same point of the compass as those of stratification, but more frequently they dip to opposite points.

"In that variety of slate which is used for roofing,"

* Geol. Trans., vol. iii. Second Series, p. 461

Professor Sedgwick, "the structure of the rock has been so modified that the traces of its original deposition are quite obliterated; and this remark does not apply merely to single quarries, but sometimes to whole mountains. We can, however, in many slate quarries, and even in hand specimens of slate, discover a number of parallel stripes, sometimes of a lighter, and sometimes of a darker colour than the general mass; and in rocks of the age I am considering, these stripes are universally parallel to the true bedding of the rocks. The proof of this is established by the fact that the assumption leads to consistent results; that these stripes are always parallel to true beds whenever such beds can be discovered, whether by organic remains, by the alternations of dissimilar deposits, or by any other ordinary means. I have seen thousands of examples of the truth of the rule, and not one exception to it among rocks of the age I am considering. Sometimes all these means fail, and we may ramble for miles among mountains of slate without seeing a single trace of their original stratification.

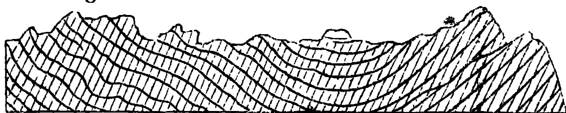
"In examining a formation of greywacké, we may find thick well-defined beds, passing into thin flaggy beds; and these, again, passing into masses subdivided into very thin laminæ. These thin laminæ often resemble the coarser varieties of slate, and are, indeed, sometimes used for the same purposes. There may, therefore, be cases where, as far as mineral structure is concerned, *slatestones* of cleavage, and *flagstones* (which are layers produced by aqueous deposition), cannot be separated from each other. These cases are, however, very rare exceptions. A *flagstone* is generally distinguished from a true slate by slight deviations in its plane; occasionally by what is called the

ripple mark; by a dull granular surface; by scattered flakes of mica, entirely unlike the continuous chloritic flakes of a true cleavage; and sometimes by organic remains studded on its surface. By such indications as these, and by the undefinable power acquired by habit, a Welsh quarry-man, accustomed to work in the upper division of the schistose groups, seldom fails to separate the laminæ of deposition from true slates; and in the same quarry he will point out the distinction between the planes of stratification and the planes of cleavage.

"I think it obvious," continues the same author, "that the contortions of slate rocks are phenomena quite distinct from cleavage, and that the curves presented by such formations are the true lines of disturbed strata."*

In the accompanying section, given by the Professor

Fig. 161.



Parallel planes of cleavage intersecting curved strata.

to illustrate these appearances in the Welsh slate rocks, we see the cleavage planes preserving an almost geometrical parallelism, while they pass through contorted strata of "hard greenish slate, obviously of sedimentary origin." A region more than thirty miles in length, and eight to ten in breadth, exhibits this structure on a magnificent scale. Many of the contorted strata "are of a coarse mechanical structure; but subordinate to them are fine, crystalline, chloritic slates. But the coarser beds and the finer, the twisted and the straight,

* Sedgwick, Geol. Trans., vol. iii. Second Series, p. 474.

have all been subjected to one change. Crystalline forces have re-arranged whole mountain masses of them, producing a beautiful crystalline cleavage, passing alike through all the strata. And again, through all this region, whatever be the contortions of the rocks the planes of cleavage pass on, generally without deviation, running in parallel lines from one end to the other, and inclining at a great angle to a point only a few degrees west of magnetic north.

"Without considering the crystalline flakes along the planes of cleavage, which prove that crystalline action has modified the whole mass, we may affirm that no retreat of parts, no contraction in dimensions in passing to a solid state, can explain such phenomena as these. They appear to me only resolvable on the supposition that crystalline or polar forces acted on the whole mass simultaneously, in given directions, and with adequate power.

"There is at first sight a difficulty in comprehending the vastness of those forces, which nature must have applied in producing such effects. But difficulties of this kind are little thought of, if we can resolve them into any known mode of material action. Now, in crystallization, there is something like a definite polarity in each particle, by which it is compelled to turn in a given direction, and group itself with other particles in definite forms; and if this modification of internal structure be carried on through a very large mass of matter, is it not probable that there is an accumulated intensity of crystalline action in each part, so that the whole intensity of crystalline force modifying the mass is not equal to the sum of the forces necessary to crystallize each part independently, but is some function of that sum, whereby it may be in-

creased almost indefinitely? I see nothing improbable in this kind of accumulated attraction, and it will explain many geological phenomena." *

"As the effects," he continues, "which have been produced through spaces of great extent are nearly uniform, the crystalline forces must have been nearly uniform, at least as to certain directions, which seems to imply a certain degree of homogeneity in the masses acted on; and, as a matter of fact, where the slaty cleavage is very perfectly brought out, the structure of the rock always makes an approach to homogeneity. Where the quartzose beds of coarse greywacké abound very much, the cleavage is seldom very perfect, or is at least confined to particular strata." †

Jointed structure. — "Besides the planes of cleavage," observes Professor Sedgwick, "we often find in large slate quarries one or more sets of cross joints, which, combined with cleavage, divide the rock into rhombohedral solids. These solids are not capable of indefinite subdivision into similar solids, except in one direction, namely, that of true cleavage; and in this way, even in hand specimens, we may generally distinguish the true cleavage planes from the joints. These last are fissures placed at definite distances from each other, the masses of rock between them having, generally speaking, no tendency to cleave in a direction parallel to them. Such a structure seems in most cases to have been produced mechanically, either by a strain upon the rock from external force, producing more or less regular sets of cracks and fissures, or by a mechanical tension on the mass, produced probably

* Sedgwick, Geol. Trans., vol iii. Second Series, pp. 477, 478.
† Sedgwick, ibid., p. 478.

by contraction, during its passage from a fluid, or semi-fluid, into a solid state. Cleavage planes are, on the contrary, the results of the ultimate chemical arrangement of the particles of a rock, and appear in most cases to be unconnected with any direct mechanical action.

"A slaty and joined structure are, however, often exhibited together; and cases may arise where it is almost impossible to decide whether a certain set of fissures are to be called joints, or cleavage planes: but difficulties of this kind are the exception, and not the rule." *

The jointed structure is common both to the stratified and unstratified rocks; but is best seen in the unstratified, as in granite, or columnar basalt. In the Swiss and Savoy Alps, Mr. Bakewell has well remarked that enormous masses of limestone are cut through so regularly by nearly vertical partings, and these are often so much more conspicuous than the seams of stratification, that an unexperienced observer will almost inevitably confound them, and suppose the strata to be perpendicular when in fact they are almost horizontal.†

The cause of this tendency to a jointed structure is by no means understood; but it appears, from recent observations, that ice sometimes presents a similar arrangement of parts. Scoresby, indeed, when speaking of the icebergs of Spitzbergen, had long ago stated, "that they are full of rents, extending perpendicularly downwards, and dividing them into innumerable columns." Colonel Jackson has lately investigated this subject more attentively, and has found that the ice

* Sedgwick, Geol. Trans., vol. iii. Second Series, pp. 480, 481.

† Introduction to Geology, chap. iv.

on the Neva, at St. Petersburg, at the beginning of a thaw, when two feet in thickness, is traversed by rows of very minute air-bubbles extending in straight lines, sometimes a little inflected, from the upper surface of the ice towards the lower, within from two to five inches of which they terminate. "Other blocks presented these bubbles united, so as to form cylindrical canals, a little thicker than a horse-hair. Observing still further," he says, "I found blocks in which the process was more advanced, and two, three, or more clefts, struck off in different directions from the vertical veins, so that a section perpendicular to the vein would represent in miniature the star-formed cracks of timber. Finally, in some pieces, these cracks united from top to bottom of the veins, separating the whole mass into vertical prisms, having a greater or less number of sides. In this state a slight shock was sufficient to detach them; and the block with its scattered fragments was in all respects the exact miniature resemblance, in crystal, of a Giant's Causeway. The surface was like a tessellated pavement, and the columns rose close, adhering and parallel, from the compact mass of a few inches at the under surface. More or less time is required for the process, which I have since seen in all its different stages." *

Stratification of granitic schists. — If we examine gneiss, which consists of the same materials as granite or mica-schist, which is a compound of quartz and mica, or hornblende schist, which is formed of hornblende and felspar, or any other member of the so-called primary division, we find that they are each made up of a succes-

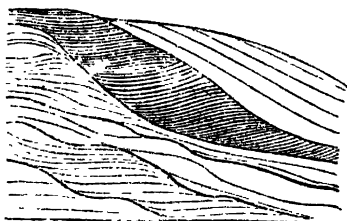
* Journ. of Roy. Geogr. Soc., vol. v. p. 19.

sion of beds, the planes of which are, to a certain extent, parallel to each other in a manner analogous to that exhibited by sedimentary formations of all ages. They may occasionally exhibit, in addition, both a jointed and a slaty structure; but they are also divided into uneven foliated layers, or in some cases into thick beds which resemble strata of deposition.

The resemblance to stratification in the granitic schists often extends very far; for the beds are occasionally contorted, or they are made up of laminæ placed diagonally, as in many sedimentary formations before described *, such laminæ not being regularly parallel like the planes of cleavage.

This disposition of the layers is illustrated in the accompanying diagram, in which I have represented

Fig. 162.



Lamination of clay-slate, Montagne de Seguinat, near Gavarnie, in the Pyrenees.

carefully the stratification of a coarse argillaceous schist, which I examined in the Pyrenees, part of which approaches in character to a green and blue roofing slate, while part is extremely quartzose, the whole mass passing downwards into micaceous schist. The vertical section here exhibited is about three feet in height, and the layers are sometimes so thin that

* See above, p. 91.

fifty may be counted in the thickness of an inch. Some of them consist of pure quartz.

Another striking point of analogy between the stratification of the crystalline formations and that of the secondary and tertiary periods, is the alternation, in each, of beds varying greatly in composition, colour, and thickness. We observe, for instance, gneiss alternating with layers of black hornblende-schist, or with granular quartz or limestone; and the interchange of these different strata may be repeated for an indefinite number of times. In like manner, mica-schist alternates with chlorite-schist, and with granular limestone in thin layers.

As we observe in the secondary and tertiary formations strata of pure siliceous sand alternating with micaceous sand and with layers of clay, so in the "primary" we have beds of pure quartz rock alternating with mica-schist and clay-slate. As in the secondary and tertiary series we meet with limestone alternating again and again with micaceous or argillaceous sand, so we find in the "primary" gneiss and mica-schist alternating with pure and impure granular limestones.

Passage of gneiss into granite. — But if we attribute the stratification of gneiss, mica-schist, and other associated rocks, to sedimentary deposition from a fluid, we encounter this difficulty, that there is often a transition from gneiss, a member of the stratified and therefore sedimentary series, into granite, which, as I have shown, is of igneous origin. Gneiss is composed of the same ingredients as granite, and its texture is equally crystalline. It sometimes occurs in thick beds, and in these the rock is often quite undistinguishable, in hand specimens, from granite; yet the lines of

stratification are still evident. These lines, it is conceived, imply deposition from water; while the passage into granite would lead us to infer an igneous origin. In what manner, then, can these apparently conflicting views be reconciled? The Huttonian hypothesis offers, I think, the only satisfactory solution of this problem. According to that theory, the materials of gneiss were originally deposited from water in the usual form of aqueous strata; but these strata were subsequently altered by subterranean heat, so as to assume a new texture. The reader will be in some degree prepared, by what has been stated in the preceding pages, to conclude, that when voluminous masses of melted and incandescent rock, accompanied by intensely heated gases under great pressure, have been for ages in contact with sedimentary deposits, they may produce great alterations in their texture; and this alteration may admit of every intermediate gradation between that resulting from perfect fusion and the slightest modification which heat can produce.

Some light has been thrown on the changes which stratified masses may undergo subsequently to their original deposition by direct experiment on the fusion of rocks in the laboratory, and still more by observations on strata in contact with igneous veins and dikes. In studying the latter class of phenomena, we have the advantage of examining the condition of the same continuous rock at some distance from the dike, where it has escaped the influence of heat, and its state where it has been near to, or in contact with, the fused mass. The changes thus exhibited may be regarded as the results of a series of experiments, made by nature on a greater scale than we can imitate, and under every variety of condition, in respect to the mineral ingredi-

ents acted upon, the intensity of heat or pressure, and the celerity or slowness of the cooling process.

Strata altered by volcanic dikes — Plass Newydd.— One of the most interesting examples of alteration in the proximity of a volcanic dike occurs near Plas Newydd, in Anglesea, described by Professor Henslow. The dike is 134 feet wide, and consists of basalt (dolerite of some authors), a compound of felspar and augite. Strata of shale and argillaceous limestone, through which it cuts perpendicularly, are altered to a distance of thirty, or even, in some places, to thirty-five feet from the edge of the dike. The shale, as it approaches the basalt, becomes gradually more compact, and is most indurated where nearest the junction. Here it loses part of its schistose structure, but the separation into parallel layers is still discernible. In several places the shale is converted into hard porcellanous jasper. In the most hardened part of the mass the fossil shells, principally *Producta*, are nearly obliterated; yet even here their impressions may frequently be traced. The argillaceous limestone undergoes analogous mutations, losing its earthy texture as it approaches the dike, and becoming granular and crystalline. But the most extraordinary phenomenon is the appearance in the shale of numerous crystals of analcime and garnet, which are distinctly confined to those portions of the rock affected by the dike.* Garnets have been observed, under very analogous circumstances, in High Teesdale, by Professor Sedgwick, where they also occur in shale and limestone altered by a basaltic dike. This discovery is most interesting, because garnets often abound in mica-schist; and we

* Trans. of Cambridge Phil. Soc., vol. i. p. 406.

see in the instance above cited that they did not previously exist in the shale and limestone, but have evidently been produced by heat or heated gases in rocks in which the marks of stratification have not been effaced.

Stirling Castle. — To select another example of alteration by dikes: the rock of Stirling Castle is a calcareous sandstone, fractured and forcibly displaced by a mass of green-stone, which has evidently invaded the strata in a melted state. The sandstone has been indurated, and has assumed a texture approaching to hornstone near the junction. So also in Arthur's Seat and Salisbury Craig, near Edinburgh, a sandstone is seen to come in contact with green-stone, and to be converted into a jaspideous rock.*

Antrim. — In several parts of the county of Antrim, in the north of Ireland, chalk with flints is traversed by basaltic dikes. The chalk is there converted into granular marble near the basalt, the change sometimes extending eight or ten feet from the wall of the dike, being greatest near the point of contact, and thence gradually decreasing till it becomes evanescent. "The extreme effect," says Dr. Berger, "presents a dark brown crystalline limestone, the crystals running in flakes as large as those of coarse *primitive* limestone; the next state is saccharine, then fine-grained and arenaceous; a compact variety, having a porcellanous aspect and a bluish-grey colour, succeeds: this, towards the outer edge, becomes yellowish white, and insensibly graduates into the unaltered chalk. The flints in the altered chalk usually assume a grey yellowish

* Illust. of Hutt. Theory, §§ 253 and 261. Dr. Macculloch, Geol. Trans., First Series, vol. ii. p. 305.

colour."* All traces of organic remains are effaced in that part of the limestone which is most crystalline.

As the carbonic acid has not been expelled, in this instance, from that part of the rock which must be supposed to have been melted, the change probably took place under considerable pressure; for Sir James Hall proved, that, under ordinary circumstances, it would require the weight of about 1700 feet of sea-water, which would be equivalent to the pressure of a column of liquid lava about 600 feet high, to prevent this acid from being given off. The experiments of Faraday have recently shown that, if carbonate of lime be perfectly dry, it may be melted under a very slight pressure, without the carbonic acid assuming a gaseous form; but it is probable that in the earth's crust calcareous rocks are rarely, if ever, entirely free from moisture.

Another of the dikes of the north-east of Ireland has converted a mass of red-sandstone into hornstone.† By another, the slate-clay of the coal-measures has been indurated, and has assumed the character of flinty slate‡; and in another place the slate-clay of the lias has been changed into flinty slate, which still retains numerous impressions of ammonites.§ One of the green-stone dikes of the same country passes through a bed of coal, which it reduces to a cinder for the space of nine feet on each side.|| Yet there are places in the north of Ireland, where the chalk is scarcely, if at

* Dr. Berger, Geol. Trans., First Series, vol. iii. p. 172.

† Rev. W. Conybeare, Geol. Trans., First Series, vol. iii. p. 201.

‡ Ibid., p. 205.

§ Ibid., p. 213.; and Playfair, Illust. of Hutt. Theory, § 253.

|| Ibid., p. 206.

all, altered by the contact of basaltic dikes, and a similar phenomenon is not unfrequent in other districts, at the junction of trap with different kinds of strata. This great inequality in the effects of the igneous rocks may often arise from an original difference in their temperature and in that of the entangled gases, such as is ascertained to prevail in different lavas, or in the same lava near its source and at a distance from it. The power also of the invaded rocks to conduct heat may vary according to their composition, structure, and the fractures which they may have experienced, and, perhaps, as I shall hint in the sequel, the quantity of steam or hot water they contain. It should also be borne in mind that in some cases the melted rock may begin to cool from the first; whereas, in other cases, although parting constantly with its heat, it may receive fresh accessions of caloric from below.

The secondary sandstones in Sky are converted into solid quartz in several places where they come in contact with veins or masses of trap; and a bed of quartz, says Dr. Macculloch, has been found near a mass of trap, among the coal-strata of Fife, which was in all probability a stratum of ordinary sandstone subsequently indurated by the action of heat.*

Alterations of strata in contact with granite.—Having selected these from innumerable examples of changes produced by volcanic dikes, we may next consider those caused by the contiguity of plutonic rocks. To some of these I have already adverted, when speaking of granite veins, and endeavouring to establish the igneous origin of granite. It was stated that the main body of the Cornish granite sends forth veins through

* Syst. of Geol., vol. i. p. 206.

the killas of that country *, — a coarse argillaceous schist, which is converted into hornblende-schist near the contact with the veins. These appearances are well seen at the junction of the granite and killas in St. Michael's Mount, a small island nearly 300 feet high, situated in the bay, at a distance of about three miles from Penzance.

The granite, says Mr. De la Beche, of Dartmoor, in Devonshire, has intruded itself into the greywacké, twisting and contorting the strata, and sending veins into them. Hence some of the slate rocks have become "micaceous, others more indurated, and with the characters of mica slate and gneiss, while others again appear converted into a hard-zoned rock strongly impregnated with felspar." †

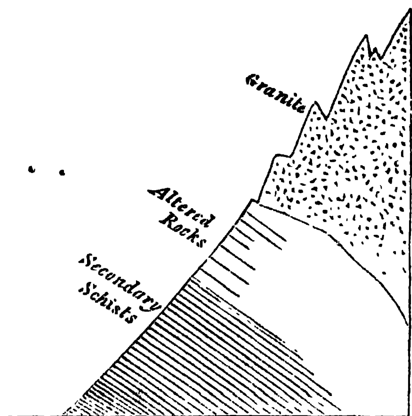
We learn from the investigations of M. Dufrénoy, that in the eastern Pyrenees there are mountain masses of granite posterior in date to the lias and chalk of that district, and that these secondary rocks are greatly altered in texture, and often charged with iron ore, in the neighbourhood of the granite. Thus, in the environs of St. Martin, near St. Paul de Fénouillet, the the chalky limestone becomes more crystalline and saccharoid as it approaches the granite, and loses all traces of the fossils which it previously contained in abundance. At some points also it becomes dolomitic, and filled with small veins of carbonate of iron, and spots of red iron-ore. At Rancié the lias nearest the granite is not only filled with iron-ore, but charged with pyrites, tremolite, garnet, and a new mineral somewhat allied to felspar, called, from the place in the Pyrenees where it occurs, "couzeranite."

* See diagram, Fig. 159.

† Geol. Manual, p. 479.

In the department of the Hautes Alpes, in France, near Vizille, M. Elie de Beaumont traced a black argillaceous limestone, charged with belemnites, to within a few yards of a mass of granite. Here the

Fig. 163.



Junction of granite with Jurassic or oolite strata in the Alps, near Champoleon.

limestone begins to put on a granular texture, but is extremely fine-grained. When nearer the junction, it becomes grey and has a saccharoid structure. In another locality, near Champoleon, a granite composed of quartz, black mica, and rose-coloured felspar, is observed partly to overlie the secondary rocks, producing an alteration which extends for about thirty feet downwards, diminishing in the beds which lie farthest from the granite. (See Fig. 163.) In the altered mass the argillaceous beds are hardened, the limestone is saccharoid, the grits quartzose, and in the midst of them is a thin layer of an imperfect granite. It is also an important circumstance, that near the point of contact, both the granite and the secondary

rocks become metaliferous, and contain nests and small veins of blende, galena, iron, and copper pyrites. The stratified rocks become harder and more crystalline, but the granite, on the contrary, softer and less perfectly crystallized near the junction.*

It will appear from sections in the Alps, described by M. Hugi, that some of the secondary beds of limestone and slate, which are in a similar manner overlaid by granite, have been altered into gneiss and mica-schist.† Some of these altered sedimentary formations are supposed, by M. Elie de Beaumont, to be of the age of the lias of England, and others to be even as modern as the Jurassic or oolite formations.

We can scarcely doubt, in these cases, that the heat communicated by the granitic mass, accompanied, perhaps, by gases at a high temperature, have reduced the contiguous strata to semifusion, and that, on cooling slowly, the rock assumed a crystalline texture. The experiments of Gregory Watt prove, distinctly, that a rock need not be perfectly melted in order that a re-arrangement of its component particles should take place, and that a more crystalline texture should ensue.‡ We may easily suppose, therefore, that all traces of shells and other organic remains may be destroyed, and that new chemical combinations may arise, without the mass being so fused as that the lines of stratification should be wholly obliterated.

In allusion to the passage from granite to gneiss, above described §, Dr. Macculloch remarks, that, "in numerous parts of Scotland, where the leading masses

* Elie de Beaumont, sur les Montagnes de l'Oisans, &c., Mém. de la Soc. d'Hist. Nat. de Paris, tome v.

† Natur. Historische Alpenreise, Soleure, 1830.

‡ Phil. Trans., 1804. § See p. 369.

of gneiss are schistose, evenly stratified, and scarcely ever traversed by granite veins, they become contorted and irregular as they approach the granite; assuming also the granitic character, and becoming intersected by veins, numerous in proportion to the vicinity of the mass. The conclusion," he adds, "is obvious; the fluid granite has invaded the aqueous stratum as far as its influence could reach, and thus far has filled it with veins, disturbed its regularity, and generated in it a new mineral character, often absolutely confounded with its own. And if the more remote beds, and those alternating with other rocks, are not thus affected, it is not only that it has acted less on those; but that, if it had equally affected them, they never could have existed, or would have been all granitic and venous gneiss." *

It should, however, be understood, that the alterations caused by volcanic dikes, granite veins, and even large masses of granite, can only afford us some analogy to those which have given rise to the metamorphic structure; for, according to the views explained in the second book (chaps. 18 and 19.), volcanic heat itself may be derived from chemical and electrical action pervading large portions of the earth's crust. This action, which, when most intense, may reduce the elements of rocks to fusion, and give rise to the most perfect granitic structure, may perhaps, when less energetic, give rise to a crystalline texture, without destroying stratification.

As to the degree of heat required to superinduce such changes, it must, in the present state of science, be matter of conjecture; but some geologists object to

* Syst. of Geol., vol. ii. p. 145.

the metamorphic theory, on the ground that rocks are extremely bad conductors of heat. Now it is worthy of consideration, how far heat, instead of being conducted through the solid parts of rocks, may be carried by heated gases through their pores; for we have seen that volcanic eruptions are attended by the evolution of steam and other gases, which rush out in enormous volume, and at a high temperature, for days, weeks, or years continuously, and which are given off by lava even after it has begun to assume a solid form. These aëriform fluids, if unable to force their way into the atmosphere, may, nevertheless, when brought into contact with rocks, pass through their pores. According to the experiments of Henry, water, under an hydrostatic pressure of ninety-six feet, will absorb three times as much carbonic acid gas as it can under the ordinary pressure of the atmosphere. Although this increased power of absorption would be diminished, in consequence of the higher temperature found to exist as we descend in the earth, yet Professor Bischoff has shown that the heat by no means augments in such a proportion as to counteract the effect of augmented pressure.* There are other gases, as well as the carbonic acid, which water absorbs, and more rapidly in proportion to the amount of pressure. Now even the most compact rocks may be regarded, before they have been exposed to the air and dried, in the light of sponges filled with water; and it is conceivable that heated gases, brought into contact with them, at great depths, may be absorbed readily, and transfused through their pores. Although the gaseous matter first absorbed would soon be con-

* Poggendorf's Annalen, No. XVI. Second Series, vol. iii.

densed, and part with its heat, yet the continued arrival of fresh supplies from below, might, in the course of ages, cause the temperature of the water, and with it that of the containing rock, to be materially raised.

M. Fournet, in his description of the metaliferous gneiss near Clermont, in Auvergne, states that all the minute fissures of the rock are quite saturated with free carbonic acid gas, which rises plentifully from the soil there and in many parts of the surrounding country. The various elements of the gneiss, with the exception of the quartz, are all softened; and new combinations of the acid, with lime, iron, and manganese, are continually in progress.*

Another illustration of the power of subterranean gases is afforded by the stufas of St. Calogero, situated in the largest of the Lipari Islands. Here, according to the description lately published by Hoffmann, horizontal strata of tuff, extending for four miles along the coast, and forming cliffs more than 200 feet high, have been discoloured in various places, and strangely altered by the "all-penetrating vapours." Dark clays have become yellow, or oftn snow-white; or have assumed a chequered and brecciated appearance, being crossed with ferruginous red stripes. In some places the fumeroles have been found by analysis to consist partly of sublimations of oxide of iron; but it also appears that veins of calcedony and opal, and others of fibrous gypsum, have resulted from these volcanic exhalations.†

I have before referred to M. Virlet's account of the corrosion of hard, flinty, and jaspideous rocks, near

* See Vol. I. p. 327.

† Hoffmann's Liparischen Inseln, p. 38. Leipzig, 1832.

Corinth, by the prolonged agency of subterranean gases*; and to Dr. Daubeny's description of the decomposition of trachytic rocks in the Solfatara, near Naples, by sulphuretted hydrogen and muriatic acid gases.†

Although in all these instances we can only study the phenomena as exhibited at the surface, it is clear that the gaseous fluids must have made their way through the whole thickness of porous or fissured rocks, which intervene between the subterranean reservoirs of gas and the external air. The extent therefore of the earth's crust, which the vapours have permeated and are now permeating, may be thousands of fathoms in thickness, and their heating and modifying influence may be spread throughout the whole of this solid mass.

The study of metaliferous veins also, especially those which are admitted to be fissures filled from below, is calculated to throw light on the manner in which heated vapours and aqueous solutions may find their way up through the interstices of rocks, raising their temperature, and sometimes transfusing into them new mineral substances. A great number of these fissures have evidently been filled in the first instance with rubbish, resulting from fragments of the adjoining rocks; and through this rubbish various siliceous, calcareous, and metallic vapours or solutions appear to have risen, causing precipitates of quartz, hornstone, calcareous spar, lead, zinc, and other metals, often perfectly distinct in their composition from any of the elements of the rocks which form the walls of such

* See Vol. III. p. 225.; and Bulletin de la Soc. Géol. de France, tom. ii. p. 330.

† See Vol. II. p. 143.; and Daubeny's Volcanos, p. 167.

fissures. Proofs are not wanting that these rents have been caused and filled at different epochs. Thus, for example, some of the silver and cobalt veins in Bohemia appear, from the observations of Mayer and Fournet, to be of the age of the chalk *, while other metaliferous veins, in the same district, were contemporaneous with a tertiary basalt.† M. Necker has also shown that a relation exists between the position of numerous metallic veins in various countries and subjacent masses of plutonic rock; so that the emanations rising from such igneous masses may, in many instances, have given rise to the more crystalline substances, whether metallic or not, which constitute the contents of the veins.

If after more fully reflecting upon those various causes of change in the composition and structure of rocks, which have only been glanced at in the above sketch, the reader conceives the possibility of a very great amount of alteration being induced in the course of time, he may be prepared to conjecture that gneiss and mica-schist may be nothing more than altered micaceous and argillaceous sandstones, and that granular quartz may have been derived from siliceous sandstone, and compact quartz from the same materials. Clay-slate may be altered shale, and shale appears to be clay which has been subjected to great pressure. Granular marble has probably originated in the form of ordinary limestone, having in many instances been replete with shells and corals now obliterated, while calcareous sands and marls have been changed into impure crystalline limestones.

* D'Aubuisson, Traité de Géog., tom. iii. p. 497.
† Ibid., p. 508.

"Hornblende-schist," says Dr. Macculloch, "may at first have been mere clay; for clay or shale is found altered by trap into Lydian stone, a substance differing from hornblende-schist almost solely in compactness and uniformity of texture."* "In Shetland," remarks the same author, "argillaceous-schist (or clay-slate), when in contact with granite, is sometimes converted into hornblende-schist, the schist becoming first siliceous, and ultimately, at the contact, hornblende-schist." †

Associated with the rocks termed primary, we meet with anthracite, just as we find beds of coal in sedimentary formations; and we know that, in the vicinity of some trap dikes, coal is converted into anthracite.

This theory, if confirmed by observation and experiment, may enable us to account for the high position in the series usually held by clay-slate relatively to hornblende-schist, as also to gneiss and mica-schist, which so commonly alternate with hornblende-schist; for we must suppose the heat which alters the strata to proceed, in almost all cases, from below upwards, and to act with greatest intensity on the inferior strata. If, therefore, several sets of argillaceous strata or shales be superimposed upon each other in a vertical series of beds in the same district, the lowest of these will be converted into hornblende-schist, while the uppermost may continue in the condition of clay-slate.

It has been objected that the chemical composition of the secondary strata differs essentially from that of the crystalline schists into which they are supposed to be convertible.‡ The "primary" schists, it is said,

* Syst of Geol., vol. i. p. 210. † Ibid., p. 211.

‡ Dr. Boase, Primary Geology, p. 319.

usually contain a considerable proportion of potash or of soda, which the secondary clays, shales and slates do not, these last being the result of the decomposition of felspathic rocks, from which the alkaline matter has been abstracted during the process of decomposition. But this reasoning proceeds on insufficient and apparently mistaken data; for a large portion of what is usually called clay, marl, shale, and slate does actually contain a certain and often a considerable proportion of alkali; so that it is difficult in many countries to obtain clay or shale sufficiently free from alkaline ingredients to allow of their being burnt into bricks or used for pottery.

Thus the argillaceous shales, as they are called, and slates of the old red-sandstone, in Forfarshire and other parts of Scotland, are so much charged with alkali, derived from triturated felspar, that instead of hardening when exposed to fire, they melt readily into a glass. They appear to consist of extremely minute grains of the various ingredients of granite, which are distinctly visible in the coarser-grained varieties, and in almost all the interposed sandstones. These laminated clays, marls, and shales might certainly, if crystallized, resemble in composition many of the primary strata.

Another objection to the metamorphic theory has been derived from the alternation of highly crystalline strata with others having a less crystalline texture. The heat, it is said, in its ascent from below must have traversed the less altered schists before it reached a higher and more crystalline bed. In answer to this, it may be observed, that if a number of strata differing greatly in composition from each other be subjected to equal quantities of heat, there is every

probability that some will be more fusible than others. Some, for example, will contain soda, potash, lime, or some other ingredient capable of acting as a flux; while others may be destitute of the same elements, and so refractory as to be very slightly affected by a degree of heat capable of reducing others to semi-fusion. Nor should it be forgotten that, as a general rule, the less crystalline rocks do really occur in the upper, and the more crystalline in the lower part of each metamorphic series.

To some it appears a phenomenon very difficult of explanation, that detached masses of granite, and even layers of it, should often occur in the midst of strata, near their contact with granite. This appearance of isolation is usually deceptive, arising from the intersection in a vertical precipice of tortuous veins of granite, as Professor Henslow has shown to be the case in several places in the cliffs of Anglesea.* I may also remark, that if unaltered sedimentary strata contained here and there layers or nests of the ingredients of granite, the rest of the mass consisting of different materials, and if the temperature of the whole has been sufficiently raised by plutonic action, the result might be, that nodules and threads of granite might be formed in certain spots only

The term "Hypogene" proposed instead of Primary.—It will appear from the reasoning explained in this and the preceding chapter, that the popular nomenclature of Geology, in reference to the rocks called "primary," is not only imperfect, but in a great degree founded on a false theory; inasmuch as some granites and granitic schists are of origin posterior to many

* Camb. Trans., vol. i.

secondary rocks. In other words, some *primary* formations can already be shown to be newer than many *secondary* groups — a manifest contradiction in terms.

Yet granite and gneiss, and the families of stratified and unstratified rocks connected with each of them, belong to one great natural division of mineral masses having certain characters in common; and it is therefore convenient that the class to which they belong should receive some common name — a name which must not be of chronological import, and must express on the one hand, some peculiarity equally attributable to granite and gneiss (to the plutonic as well as the *altered* rocks), and which, on the other, must have reference to characters in which those rocks differ, both from the volcanic and from the *unaltered* sedimentary strata. I propose the term "hypogene" for this purpose, derived from *ὑπο*, *subter*, and *γινομαι*, *nascor*; a word implying the theory that granite and gneiss are both *nether-formed* rocks, or rocks which have not assumed their present form and structure at the surface. It is true that gneiss and all stratified rocks must have been deposited originally at the surface, or on that part of the surface of the globe which is covered by water; but, according to the views explained in this and the foregoing chapter, they could never have acquired their crystalline texture, unless acted upon by heat and chemical forces under pressure in those regions, and under those circumstances where the plutonic rocks are generated.

The term "Metamorphic" proposed for stratified primary.—We may divide the hypogene rocks, then, into the unstratified, or plutonic, and the *altered* stratified. For these last the term "metamorphic" (from *μετα*, *trans*, *μορφη*, *forma*,) may be used. The last-

mentioned name need not, however, be often resorted to, because we may speak of hypogene *strata*, hypogene *limestone*, hypogene *schist;* and this appellation will suffice to distinguish the formations so designated from the plutonic rocks. By referring to the table (No. II. p. 402.), the reader will see the chronological relation which I conceive the two classes of hypogene rocks to bear to the strata of different ages.

No order of succession in hypogene formations. — When we regard the tertiary and secondary formations simply as mineral masses uncharacterized by organic remains, we perceive an indefinite series of beds of limestone, clay, marl, siliceous sand, sandstone, coal, and other materials, alternating again and again without any fixed or determinate order of position. The same may be said of the hypogene formations; for in these a similar want of arrangement is manifest, if we compare those occurring in different countries. Gneiss, mica-schist, hornblende-schist, quartz rock, hypogene limestone, and the rest, have no invariable order of superposition, although, for reasons above explained, clay-slate must usually hold a superior position relatively to hornblende-schist.

I do not deny that, in a particular mountain-chain, a chronological succession of hypogene formations may be recognized, for the same reason that in a country of limited extent there is an order of position in the secondary and tertiary rocks, limestone predominating in one part of the series, clay in another, siliceous sand in a third, and so of other compounds. It is probable that a similar prevalence of a regular order of arrangement in the hypogene series throughout certain districts led the earlier geologists into a belief that they should be able to fix a definite order of succession

for the various members of this great class throughout the world.

That expectation has certainly not been realized; yet was it more reasonable than the doctrine of the universality of particular kinds of rock which were admitted to be of sedimentary origin; for there is undoubtedly a remarkable identity in the mineral character of the hypogene formations, both stratified and unstratified, in all countries; although the notion of a uniform order of succession in the different groups must be abandoned.

The student may, perhaps, object to the views above given of the relation of the sedimentary and metamorphic rocks, on the ground that there is frequently, indeed usually, an abrupt passage from one to the other. This phenomenon, however, admits of the same explanation as the fact that the beds of lakes and seas are now frequently composed of hypogene rocks. In these localities the hypogene formations have been brought up near to the surface, and laid bare by denudation. New sedimentary strata are thrown down upon them, and in this manner the two classes of rocks, the aqueous and the hypogene, come into immediate contact, without any gradation from one to the other. As we suppose the plutonic and metamorphic rocks to have been uplifted at all periods in the earth's history, so as to have formed the bottom of the ocean and of lakes, by the same operations which have carried up marine strata to the summits of lofty mountains, we must suppose the juxtaposition of the two great orders of rocks, now alluded to, to have been a necessary result of all former revolutions of the globe.

But occasionally a transition is observable from strata containing shells, and displaying an evident mechanical

structure, to others which are partially altered; and from these again we sometimes pass insensibly into the hypogene series. Some of the argillaceous schists in Cornwall are of this description, being undistinguishable from the hypogene schists of many countries, and yet exhibiting, in a few spots, faint traces of organic remains. In parts of Germany, also, there are schists which, from their chemical condition, must be called metamorphic; yet which are interstratified with greywacké, a rock probably modified by heat, but which contains casts of shells, and often displays unequivocal marks of being an aggregate of fragments of pre-existing rocks.

The same observation holds true in respect to the Cumbrian and Welsh slate rocks before alluded to as described by Professor Sedgwick.* They are metamorphic slates alternating with a few mechanical and fossiliferous beds. If it be asked by what characters we can draw the line and determine where the metamorphic series ends, and the sedimentary begins, I reply that, if this be difficult or impossible, it only strengthens the argument adduced in the preceding part of this chapter; for, according to the theory proposed, we must expect to find strata in every intermediate condition between the most and the least altered.

Had Werner's term "transition" been restricted exclusively to certain peculiarities of mineral structure, and never connected with the presence of particular species of fossils, in consequence of which it soon acquired a chronological import, that term might have been conveniently retained to designate an intermediate condition of strata when they exhibit

* See p. 361.

the characters of rocks of the metamorphic series with occasional traces of a mechanical structure and organic remains.

Some geologists, who shrink from the theory that all the hypogene strata, beautifully compact and crystalline as they are, have once been in the state of ordinary mud, clay, marl, sand, gravel, and limestone, such as are now forming beneath the waters, resort, in their desire to escape from such conclusions, to the hypothesis, that *chemical causes* once acted with intense energy, and that by their influence purely crystalline strata were precipitated; a theory which to me appears as mysterious and unphilosophical as the doctrine of a "plastic virtue," introduced by the earlier writers to explain the origin of fossil-shells and bones.

Relative age of the visible hypogene rocks. — It was stated, at the close of the last chapter, that a great portion of the plutonic rocks now visible are of higher antiquity than the oldest secondary strata; the same may be said of the stratified hypogene formations, which are therefore entitled to the appellation of primary, in the strict sense of the word, as anterior in age to the greywacké, or oldest known fossiliferous group. But we can, in some instances, demonstrate that there are granites of posterior origin to certain secondary strata, and that *secondary* strata have been converted into the *metamorphic.* Examples of such phenomena are rare, and their rarity is quite consistent with the theory, that the hypogene formations, both stratified and unstratified, may have been always generated in nearly equal quantities during periods of equal duration.

I conceive that the granite and gneiss of periods more recent than the carboniferous and greywacké formations are still, for the most part, concealed; and

those portions which are visible can rarely be shown, by geological evidence, to have originated during secondary periods. It is very possible, for example, that considerable tracts of hypogene strata in the Alps may be altered oolite, altered lias, or altered secondary rocks inferior to the lias; but we can scarcely ever hope to substantiate the fact, because, whenever the change of texture is complete, no characters remain to afford us any insight into the probable age of the mass. Where granite happens to have intruded itself in such a manner as partially to overlie a mass of lias or other strata, as in the case before alluded to (Fig. 163., p. 376.), we may prove that *fossiliferous* strata have been converted into gneiss, mica-schist, clay-slate, or granular marble; but if the action of the heat upon the strata had been more intense, these inferences could not have been drawn; and it might then have been supposed that no alpine hypogene strata were newer than the oldest secondary rocks.

Considerable difficulty and misapprehension, in regard to the antiquity of the metamorphic rocks, may arise from the circumstance of their having been deposited at one period, and having assumed their crystalline texture at another. Thus, for example, if an Eocene granite should invade the lias, and superinduce a hypogene structure, to what period shall we refer the altered strata? Shall we say that they are metamorphic rocks of the Eocene or Liassic eras? They assumed their stratified form when the animals and plants of the lias flourished; they have become metamorphic during the Eocene period. It would be preferable, in such instances, I think, to consider them as hypogene strata of the Eocene period, or of that in which they were altered; yet it would rarely be possible to esta-

blish their true age. For this purpose we ought to know the granite, to which the change of texture was due, to be newer than the lias which it penetrated; but there would rarely be any data to show that this granite might not have been injected at the close of the Liassic period, or at some much later era.

The metamorphic rocks must in all cases be the oldest, that is to say, they must lie at the bottom of each series of superimposed strata; but the hypogene strata of one country may be, and frequently are, of a very different age from those of another. The greater part, however, of the visible hypogene rocks are, probably, more ancient than the oldest fossiliferous formations. In the latter, we frequently discover pebbles of hypogene rocks, namely, granite, gneiss, mica-schist, and clay-slate; and the carboniferous rocks often rest upon the hypogene, without exhibiting any marks of change at the junction. According to the views before explained of the operations of earthquakes, we ought not to expect plutonic and metamorphic rocks of the more modern eras to have reached the surface generally; for we must suppose many geological periods to elapse before a mass, which has assumed its particular form far below the level of the sea, can have been upraised and laid open to view above that level. Beds containing marine shells sometimes appear in the principal mountain-chains, at the height of two or three miles above the sea; but they always belong to formations of considerable antiquity: still more, then, should we be prepared to find the hypogene rocks now in sight to be of high relative antiquity, since, before they could be brought up to view, they must probably have risen from a site far inferior to the bottom of the ocean.

The cause of the great age of the plutonic and metamorphic rocks, *now in sight*, may be elucidated by a familiar illustration. Suppose two months to be the usual time required for passing from some tropical country to our island, and that an annual importation takes place of a certain species of insect which can be reared only in the climate of that equatorial country, and the ordinary term of whose life is two months. It is evident that no living individuals of that species could ever be seen in England except in extreme old age. The young may come annually into the world in great numbers; but, in order to see them, we must travel to lands near the equator.

In like manner, if the hypogene rocks can originate only at great depths in the regions of subterranean heat, and if it requires many geological epochs to raise them to the surface, they must be very ancient before they make their appearance in the superficial parts of the earth's crust. They may still be forming in every century, and they may have been produced in equal quantities during each successive geological period of equal duration; but in order to see them in a nascent state, slowly consolidating from a state of fusion, or semi-fusion, it would be necessary to descend into the "fuelled entrails" of the earth.

In the accompanying diagram, Fig. 164., an attempt is made to show the inverted order in which the sedimentary and plutonic formations may occur in the earth's crust; subterposition in the plutonic, like superposition in the sedimentary rocks, being for the most part characteristic of a newer age.

The oldest plutonic rock, No. I., supposed to have consolidated from a state of fusion before any of the fossiliferous rocks now on the surface were deposited,



Diagram showing the relative position which the hypogene and sedimentary formations of different ages may occupy.

I. Primary plutonic.
II. Secondary plutonic.
III. Tertiary plutonic.
IV. Recent plutonic.

4. Recent strata.
3. Tertiary strata.
2. Secondary strata.
1. Primary metamorphic rocks.

has been upheaved at successive periods until it has become exposed to view in a mountain-chain. This protusion of No. I. has been caused by the igneous agency which produced the new plutonic rocks Nos. II. III. and IV. Part of the metamorphic rocks No. 1. have also been raised to the surface by the same gradual process. It will be observed that the Recent *strata* No. 4. and the Recent plutonic rock No. IV. are the most remote from each other in position, although of contemporaneous date. According to this hypothesis the convulsions of many periods will be required before *Recent* granite will be upraised so as to form the highest ridges and central axes of mountain-chains. During that time the *Recent* strata No. 4. might be covered by a great many newer sedimentary formations.

As the progress of decay and reproduction by aqueous agency is incessant on the surface of the continents, and in the bed of the ocean, while the hypogene rocks are generated below, or are rising gradually from the volcanic foci, there must ever be a remodelling of the earth's surface in the time intermediate between the origin of each set of plutonic and metamorphic rocks, and the protrusion of the same rocks into the atmosphere or the ocean. Suppose the principal source of the Etnean lavas to lie at the depth of ten miles, we may easily conceive that before they can be uplifted to the day several distinct series of earthquakes must occur, and between each of these there might usually be one or many periods of tranquillity. The time required for so great a development of subterranean movements might well be protracted until the deposition of a series of sedimentary

rocks, equal in extent to all our secondary and tertiary formations, had taken place.

The relative age, therefore, of the *visible* plutonic and metamorphic rocks, as compared to the unaltered sedimentary strata, must always be determined by the relations of two forces — the power which uplifts the hypogene rocks, and that aqueous agency which de-degrades and renovates the earth's surface; or, in other words, the relative age must depend on the quantity of aqueous action which takes place between two periods — that during which the heated and melted rocks are cooled and consolidated in the nether regions, and that of their emergence at the earth's surface.

Volume of hypogene rocks supposed to have been formed since the Eocene period. — If we were to indulge in speculations on the probable quantity of hypogene formations, both stratified and unstratified, which may have been formed beneath Europe and the European seas since the commencement of the Eocene period, it might be conjectured that the mass has equalled, if not exceeded in volume, the entire European continent. The grounds of this opinion will be understood by reference to what I have said of the causes which may have upheaved part of Sicily to its present height above the level of the sea since the beginning of the Newer Pliocene period.* If the theory which, in that instance, attributes the disturbance and upheavings of the superficial strata to the action of subterranean heat be deemed admissible, the same argument will apply with no less force to every other district, elevated or depressed, since the commencement of the tertiary period.

* See p. 5.

But the remarks on the map of Europe, in the first book, have shown, that the conversion of sea into land, since the Eocene period, embraces an area equal to the greater part of Europe; and that even those tracts which had in part emerged before the Eocene era, such as the Alps, Apennines, and other mountain-chains, have risen to the additional altitude of from one thousand to four thousand feet since that era. I have also suggested the probability of a great amount of subsidence, and the conversion of considerable portions of European land into sea, during the same period, — changes which may be supposed to arise from the influence of subterranean heat.

From these premises we may conclude, that the liquefaction and alteration of rocks, by the operation of volcanic heat at successive periods, has extended over a subterranean space, equal at least in area to the present European continent, and has often pervaded a portion of the earth's crust four thousand feet or more in thickness.

The principal effect of these volcanic operations in the nether regions, during the tertiary periods, or since the existing species began to flourish, has been to heave up to the surface hypogene formations of an age anterior to the carboniferous. The repetition of another series of movements, of equal violence, might upraise the plutonic and metamorphic rocks of many of the secondary periods; and if the same force should still continue to act, the next convulsions might bring up the *tertiary* and *recent* hypogene rocks; by which time we may imagine that nearly all the sedimentary strata now in sight would either have been destroyed by the action of water, or have assumed the meta-

morphic structure, or would have been melted down into plutonic and volcanic rocks.

At the end of this chapter will be found a table of the chronological relations of the principal divisions of rocks, according to the views above set forth. The sketch is confessedly imperfect; but it will elucidate the theory above suggested, of the connection which may exist between the hypogene rocks of different periods, and the alluvial, volcanic, and sedimentary formations.

Concluding Remarks.

In the history of the progress of geology, it has been stated that the opinion originally promulgated by Hutton, "that the strata called *primitive* were mere altered sedimentary rocks," was vehemently opposed for a time, on the ground of its supposed tendency to promote a belief in the past eternity of our planet.* Before that period the absence of animal and vegetable remains in the so-called primitive strata had been appealed to, as proving that there had been an era when the planet was uninhabited by living beings, and when, as was also inferred, it was uninhabitable, and, therefore, probably in a nascent state.

The opposite doctrine, that the oldest visible strata might be the monuments of an antecedent period, when the animate world was already in existence, was declared to be equivalent to the assumption that there never was a beginning to the present order of things. The unfairness of this charge was clearly pointed out by Playfair, who observed, "that it was

* Vol. I. p. 91.

one thing to declare that we had not yet discovered the traces of a beginning, and another to deny that the earth ever had a beginning."

I regret, however, to find that the bearing of my arguments in the first book has been misunderstood in a similar manner; for I have been charged with endeavouring to establish the proposition, that, "the existing causes of change have operated with absolute uniformity from all eternity."*

It is the more necessary to notice this misrepresentation of my views, as it has proceeded from a friendly critic, whose theoretical opinions coincide in general with my own; but who has, in this instance, strangely misconceived the scope of the argument. With equal justice might an astronomer be accused of asserting that the works of creation extended throughout *infinite* space, because he refuses to take for granted that the remotest stars now seen in the heavens are on the utmost verge of the material universe. Every improvement of the telescope has brought thousands of new worlds into view; and it would, therefore, be rash and unphilosophical to imagine that we already survey the whole extent of the vast scheme, or that it will ever be brought within the sphere of human observation.

But no argument can be drawn from such premises in favour of the infinity of the space that has been filled with worlds; and if the material universe has any limits, it then follows that it must occupy a minute and infinitesimal point in infinite space.

So if, in tracing back the earth's history, we arrive

* Quarterly Review, No. 86., Oct. 1830, p. 464.

at the monuments of events which may have happened millions of ages before our times, and if we still find no decided evidence of a commencement, yet the arguments from analogy in support of the probability of a beginning remain unshaken; and if the past duration of the earth be finite, then the aggregate of geological epochs, however numerous, must constitute a mere moment of the past, a mere infinitesimal portion of eternity.

It has been argued, that, as the different states of the earth's surface, and the different species by which it has been inhabited, have all had their origin, and many of them their termination, so the entire series may have commenced at a certain period. It has also been urged, that, as we admit the creation of man to have occurred at a comparatively modern epoch — as we concede the astonishing fact of the first introduction of a moral and intellectual being — so also we may conceive the first creation of the planet itself.

I am far from denying the weight of this reasoning from analogy; but, although it may strengthen our conviction, that the present system of change has not gone on from eternity, it cannot warrant us in presuming that we shall be permitted to behold the signs of the earth's origin, or the evidences of the first introduction into it of organic beings. We aspire in vain to assign limits to the works of creation in *space*, whether we examine the starry heavens, or that world of minute animalcules which is revealed to us by the microscope. We are prepared, therefore, to find that in *time* also the confines of the universe lie beyond the reach of mortal ken. But in whatever direction we pursue our researches, whether in time

or space, we discover every where the clear proofs of a Creative Intelligence, and of His foresight, wisdom, and power.

As geologists, we learn that it is not only the present condition of the globe which has been suited to the accommodation of myriads of living creatures, but that many former states also have been adapted to the organization and habits of prior races of beings. The disposition of the seas, continents, and islands, and the climates, have varied; the species likewise have been changed; and yet they have all been so modelled, on types analogous to those of existing plants and animals, as to indicate throughout a perfect harmony of design and unity of purpose. To assume that the evidence of the beginning or end of so vast a scheme lies within the reach of our philosophical inquiries, or even of our speculations, appears to be inconsistent with a just estimate of the relations which subsist between the finite powers of man and the attributes of an Infinite and Eternal Being.

TABLE II.

Showing the Relations of the Alluvial, Aqueous, Volcanic, and Hypogene Formations of different Ages.

	Periods.	Formations.		Some of the Localities where the Formations occur.
I. Recent.	A. Table I. p. 308.	Alluvial.	- - -	Beds of existing rivers, &c., book iii. ch. xiv.
		Aqueous.	*a.* Marine.	Coral reefs of the Pacific, book iii. ch. xviii.
			b. Freshwater.	Bed of Lake Superior, &c., book ii. ch. iv.
		Volcanic.	- - -	Etna, Vesuvius, book ii. chs. x. xi. xii.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of active volcanos, book iv. ch. xxvi.
			b. Metamorphic.	*Concealed;* around the foci of active volcanos, book iv. ch. xxvii.
II. Tertiary.	1. Newer Pliocene. B. Table I. p. 308.	Alluvial.	- -	Gravel covering the Newer Pliocene strata of Sicily.
		Aqueous.	*a.* Marine.	Val di Noto, Sicily.
			b. Freshwater.	Colle, in Tuscany.
		Volcanic.	- - -	Val di Noto, Sicily.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of Newer Pliocene volcanos—underneath the Val di Noto, Vol. IV. p. 5., and book iv. ch. xxvii.
			b. Metamorphic.	*Concealed;* near the foci of Newer Pliocene volcanos—underneath the Val di Noto, Vol. IV. p. 5. and book iv. ch. xxvii.

TABLE II. — *continued.*

	Periods.	Formations.		Some of the Localities where the Formations occur.
II. TERTIARY — *continued.*	2. Older Pliocene. C. Table I. p. 308.	Alluvial.	- - -	Norfolk? Vol. IV. p. 91.
		Aqueous.	*a.* Marine.	Subapennine formations, Vol. IV. p. 63.
			b. Freshwater.	Near Sienna, Vol. IV. p. 69.
		Volcanic.	- - -	Tuscany, Vol. IV. p. 68.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of Older Pliocene volcanos — beneath Tuscany.
			b. Metamorphic.	*Concealed;* probably near the same foci.
	3. Miocene. D. Table I. p. 308.	Alluvial.	- - -	Mont Perrier, Auvergne — Orleanais, Vol. IV. pp. 147. 150.
		Aqueous.	*a.* Marine.	Bordeaux. Dax.
			b. Freshwater.	Saucats, near Bordeaux, Vol. IV. p. 134.
		Volcanic.	- - -	Hungary, Vol. IV. p. 153.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of Miocene volcanos — beneath Hungary.
			b. Metamorphic.	*Concealed;* probably around the same foci.
	4. Eocene. E. Table I. p. 309.	Alluvial.	- - -	Summit of North and South Downs? Vol. IV. p. 276.
		Aqueous.	*a.* Marine.	Paris and London basins.
			b. Freshwater.	Isle of Wight — Auvergne.
		Volcanic.	- - -	Ronca, Vicentine, Vol. IV. p. 224.; oldest volcanic rocks of the Limagne d'Auvergne, book iv. ch. xix.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of Eocene volcanos — beneath Vicentine and the Limagne d'Auvergne.
			b. Metamorphic.	*Concealed;* probably near the same foci.

TABLE II. — *continued.*

	Periods.	Formations.		Some of the Localities where the Formations occur.
III. SECONDARY.	1. Cretaceous group. F. Table I. p. 309.	Alluvial.		
		Aqueous.	a. Marine. b. Freshwater.	Wiltshire, North Downs. Flamborough Head.
		Volcanic.	- - -	Northern Flanks of the Pyrenees? Near Dax?
		Hypogene.	a. Plutonic. b. Metamorphic.	
	2. Wealden group. G. Table I. p. 309.	Alluvial.	- - -	Portland "Dirt-bed" (containing pebbles).
		Aqueous.	a. Marine. b. Freshwater.	Weald of Surrey, Kent, and Sussex, book iv. ch. xxi.
		Volcanic.		
		Hypogene.	a Plutonic. b. Metamorphic.	
	3. Oolite group. H. Table I. p. 310.	Alluvial.		
		Aqueous.	a. Marine. b. Freshwater.	Oxford. Bath. Jura chain.
		Volcanic.	- - -	Hebrides?
		Hypogene.	a. Plutonic. b. Metamorphic.	*Concealed*; beneath the Hebrides.
	4. Lias group. I. Table I. p. 311.	Alluvial.		
		Aqueous.	a. Marine. b. Freshwater.	Lyme Regis. Whitby. Aberthaw.
		Volcanic.	- - -	Hebrides?
		Hypogene.	a. Plutonic. b. Metamorphic.	Alps? book iv. ch. xxvii. Valorsine in Savoy?
	5. New Red Sandstone and Magnesian limestone group. K. & L. Table I. p. 311.	Alluvial.		
		Aqueous.	a. Marine. b. Freshwater.	Cheshire. Staffordshire. Vosges. Westphalia (Muschelkalk).
		Volcanic.	- - -	Near Exeter, Devon.
		Hypogene.	a. Plutonic. b. Metamorphic.	*Concealed*; beneath Devonshire?

TABLE II. — *continued.*

Periods.		Formations.		Some of the Localities where the Formations occur
III. Secondary — *continued.*	6. Carboniferous & Old Red Sandstone group. M. & N. Table I. p. 312.	Alluvial.		
		Aqueous.	*a* Marine.	Clifton. Mendip. Edinburgh.
			b. Freshwater.	Coal measures of North of England and near Edinburgh.
		Volcanic.	- - -	Forfarshire. Edinburgh. Fife. Durham. High Teesdale.
		Hypogene.	*a.* Plutonic.	*Concealed;* beneath Edinburgh, Northumberland, Durham.
			b. Metamorphic.	Near the Plutonic rocks of the same period.
IV. Transition.	7. Silurian & Greywacké group. O. & P. Table I. p. 313.	Alluvial.		
		Aqueous.	*a.* Marine.	Wenlock, Shropshire.
			b. Freshwater.	
		Volcanic.	- - -	Shropshire.
		Hypogene.	*a.* Plutonic.	*Concealed;* beneath Shropshire.
			b. Metamorphic.	Near the Plutonic rocks of the same period.
V. Primary Rocks.*		Alluvial. Aqueous. Volcanic.	- - -	Probably all destroyed by denudation, or converted into hypogene.
		Hypogene.	Plutonic.	Perhaps a considerable part of the granite now visible.
			Metamorphic.	Probably a large proportion of the gneiss, mica-schist, and other stratified crystalline rocks now visible.

* By primary formations are meant those, whether stratified or unstratified, which are older than the most ancient European rocks (the transition or greywacké), in which distinct fossils have as yet been discovered.

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